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Multimedia Pollution Assessment of the Wood Products Industries

Jordan (Edward C.) Co., Inc., Portland, ME

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Industrial Environmental Research Lab.
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MULTIMEDIA POLLUTION ASSESSMENT OF THE WOOD PRODUCTS INDUSTRIES

by

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No. 68-03-2605

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Office of Research and Development
U.S. Environmental Protection Agency
Cincinnati, Ohio 45268

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16. ABSTRACT

This report presents a summary and commentary on pollutants, abatement technologies, and regulations in the wood products industries. Industries included in the study are pulp, paper and paperboard, veneer/plywood, particleboard, millwork and structural members, fabricated wood products, fabricated paper products, and gum and wood chemicals, and wood preserving. Water pollution abatement legislation has established guidelines based on Best Practicable Control Technology Currently Available (BPCTCA). These guidelines primarily address conventional pollutants, including five-day biochemical oxygen demand (BOD_5), total suspended solids (TSS) and pH. In addition, guidelines based on Best Available Technology Economically Achievable (BATEA) and Best Conventional Pollutant Gontrol Technology (BCPCT) are currently being established to address conventional, priority (toxic), and nonconventional (neither conventional nor toxic) pollutants. Existing external air pollution control devices, in conjunction with internal process controls, can be effective in the reduction of air pollutants, especially particulates and sulfur dioxide. Although many wood wastes are burned for heat recovery, sludge and refuse are typically disposed of in landfills. Since sludges generated by the wood preserving segment are considered a hazardous waste under RCRA (May, 1980), new landfilling practices will need to be met by the industry for disposal.

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NOTICE

This document has been reviewed in accordance with U.S. Environmental Protection Agency policy and approved for publication. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

FOREWORD

When energy and material resources are extracted, processed, converted, and used, the related pollutional impacts on our environment and even on our health often require that new and increasingly more efficient pollution control methods be used. The Industrial Environmental Research Laboratory - Cincinnati (IERL-Ci) assists in developing and demonstrating new and improved methodologies that will meet these needs both efficiently and economically.

This report assesses multimedia pollution control in wood products industries through February 1979. The data presented in the report on the pulp, paper, and paperboard industry and the Resource Conservation Recovery Act (RCRA) were updated through May 1980.

A summary of legislative requirements for establishment of emission standards are presented. This report should be useful to EPA personnel concerned with environmental quality related to the wood products industries and other Federal agency personnel concerned with wood treatment processes.

For further information on these subjects, interested readers should contact the Food and Wood Products Branch of the Industrial Pollution Control Division.

David G. Stephan
Director
Industrial Environmental Research Laboratory
Cincinnati

ABSTRACT

This report presents a summary and commentary on pollutants, abatement technologies, and regulations in the wood products industries. Information was primarily obtained from a study performed by Battelle Laboratories for the U.S. Environmental Protection Agency and available effluent guidelines development.

Water pollution abatement legislation has established guidelines based on Best Practicable Control Technology Currently Available (BPCTCA). These guidelines primarily address conventional pollutants, including five-day biochemical oxygen demand (BOD_5), total suspended solids (TSS) and pH. In addition, guidelines based on Best Available Technology Economically Achievable (BATEA) and Best Conventional Pollutant Control Technology (BCPCT) are currently being established to address conventional, priority (toxic), and nonconventional (neither conventional nor toxic) pollutants.

Existing external air pollution control devices, in conjunction with internal process controls, can be effective in the reduction of air pollutants, especially particulates and sulfur dioxide. Air pollutants often limited by state governments include particulates and sulfur dioxide, as well as total reduced sulfur (TRS) compounds. Generally, southern states have stricter particulate standards, while northwestern states have stricter reduced sulfur compounds standards. The major impacts associated with these pollutants are odor problems and potential respiratory effects.

Solid waste generation in the wood products industry consists primarily of wood wastes, wastewater treatment plant sludge and refuse generated by personnel activities. Although many wood wastes are burned for heat recovery, sludge and refuse are typically disposed of in landfills. Since sludges generated by the wood preserving segment are considered a hazardous waste under RCRA (May 1980), new landfilling practices will need to be met by the industry for disposal.

This report was submitted in fulfillment of Contract No. 68-03-2605 by the Edward C. Jordan Co., Inc. under the sponsorship of the U.S. Environmental Protection Agency. This report covers the period May 1, 1978, to June 1980, and work was completed as of June 1980.

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ABBREVIATIONS

AC --alternating current
ACA --ammonical copper arsenite
ADT --air dry ton
ASB --aerated stabilization basin
BACT --best available control technology
BART --best available retrofit technology
BATEA --best available technology economically achievable
BMP'S --best management practices
BOD$_5$ --biochemical oxygen demand (five-day)
BPCTCA (BPT) --best practicable control technology currently available
CMN --coarse, molded, newsprint
CMP --chemi-mechanical pulp
COD --chemical oxygen demand
DO --dissolved oxygen
EPA --Environmental Protection Agency
ESP --electrostatic precipitators
GAC --granular activated carbon
gal --gallon(s)
kks/day --1,000 kilograms per day
ks/ha --kilograms per hectare
kwh --kilowatt-hour
lb --pound(s)
mg/l --milligram(s) per liter
mst --median survival time
Na --sodium
NAAQS --national ambient air quality standards
NSSC --neutral sulfite semi-chemical
NTU --nephelometric turbidity unit
PCB --polychlorinated biphenyls
PCP --pentachlorophenol
PSD --prevention of significant deterioration
Pt-Co --platinum cobalt unit(s)
RBC --rotating biological contactor
RCRA --resource conservation and recovery act
SIP --state implementation plan
t --2,000 pounds (short ton)
TOC --total organic carbon
TRS --total reduced sulfur
TSP --total suspended particulates
TSS --total suspended solids
TU --toxic unit
ug/l --microgram(s) per liter
Z/A --Zurn/Attisholz

METRIC CONVERSION FACTORS

The U.S. Environmental Protection Agency (EPA) policy is to express all measurements in metric units. When this results in undue cost or lack of clarity, conversion factors are provided for the nonmetric units used in the report. Generally, this report uses English units of measure. For conversion to the metric system, use the following conversion factors.

TABLE OF CONVERSION FACTORS

Multiply english unit	By conversion factor	To obtain metric (SI)unit
Acres	0.405	hectares
Acre-feet	1233.5	cubic meters
Barrel, oil	158.97	liters
British Thermal Unit	0.252	kilogram-calories
British Thermal Unit/pound	0.555	kilogram calories/kilogram
Cubic feet/minute	0.028	cubic meters/minute
Cubic feet/second	1.7	cubic meters/minute
Cubic feet	0.028	cubic meters
Cubic feet	28.32	liters
Cubic inches	16.39	cubic centimeters
Degree Fahrenheit	0.555(°F-32)*	degree centrigrade
Feet	0.3048	meters
Gallon	3.785	liters
Gallon/minute	0.0631	liters/second
Horsepower	0.7457	kilowatts
Inches	2.54	centimeters
Inches of mercury	0.03342	atmospheres
Pounds	0.454	kilograms
Million gallons/day	3785	cubic meters/day
Mile	1.609	kilometer
Pound/square inch (gauge)	0.06805 psig +1*	atmospheres (absolute)
Square feet	0.0929	square meters
Square inches	6.452	square centimeters
Tons (short)	0.907	metric tons (1000 kilograms)
Yard	0.9144	meters

*Actual conversion, not a multiplier.
Source: Battelle Columbus Laboratories (166).

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The constructive comments received from Donald Wilson and other EPA staff members in their review of preliminary drafts of the report are sincerely appreciated.

Much of the material herein was summarized from documents previously prepared for the EPA, most notably:

1. P.S.K., Choi, W.J. Mueller, J.A. Jacomet, D.L. Hessel, J.A. Gerling, and T.J. Collier. "Multimedia Pollution Assessment in Pulp, Paper and Other Wood Products Industry," of Battelle Columbus Laboratories, Columbus, Ohio 1976 (unpublished)

2. "Cross Media Impact of the Disposal of Hazardous Wastes From the Wood Products and Related Industries," by Battelle Columbus Laboratories, Columbus, Ohio (unpublished).

The efforts of these and other authors in gathering much of the base data included in this report is acknowledged and appreciated.

SECTION 1

INTRODUCTION

OBJECTIVES

This report is intended as a summary and commentary on pollutants, abatement technologies and regulations in the wood products industries.

Summarized in this document are:

1. Wastewater effluent, air emissions and solid waste generated by the wood products industries, and associated environmental impacts;

2. Abatement technology and associated effects and economics; and

3. Pertinent existing and proposed legislation and its relation to items 1 and 2 above.

The primary basis of this report is a study performed by Battelle Laboratories for the U.S. Environmental Protection Agency (EPA). Available information from effluent guidelines development and other sources has been used to update and expand data from the Battelle effort.

The wood products industries, for the purpose of this report, have been broken down into two main groups: 1) the pulp, paper, and paperboard industry; and 2) the other wood products industries. A brief description of each and its subcategories is presented in the following paragraphs.

INDUSTRY DESCRIPTION

Pulp, Paper, and Paperboard

At the time of this study, the pulp, paper, and paperboard industry consisted of approximately 730 operating facilities. Of these 514 have been classed in specific subcategories, and the remainder are in miscellaneous subcategories composed of combined process or unique process mills. Operations vary from large integrated kraft pulp, paper, and paperboard mills producing over 1.8 million kilograms per day or 2,000 tons/day, to small nonintegrated single machine mills making less than 0.9 kkg/day (1 ton/day) of product.

There are three general classifications of mills: Integrated mills; secondary fiber mills, and nonintegrated mills. At integrated mills, pulp is produced from wood and nonwood raw materials (e.g., hemp or flax); paper and board products are produced onsite. At secondary fiber mills, no pulp is produced onsite; most of its furnish is derived from wastepaper. At nonintegrated mills, the furnish consists of purchased wood pulp or other fibers. No pulp is made onsite, but some wastepaper can be used, as long as the mill does not have a complete deinking process.

Pulping processes at the integrated mills range from simple groundwood operations, using only mechanical defibration of full logs and limited bleaching operations, to the complex dissolving pulp mills employing extensive chemical pulping operations and attendant recovery systems coupled with multistage bleaching operations. Also included with the integrated pulp mills are those producing pulps from a variety of nonwood fibers such as flax, hemp, cotton, abaca, and sisal. Pulping operations include groundwood and modified groundwood operations, sulfite (acid) processes, unbleached and bleached kraft or soda processes (alkaline), and modified high-yield processes utilizing mild chemical treatments coupled with mechanical defibration.

Mills using secondary fiber are a large and growing segment of the industry. At these mills wastepaper is utilized in various forms. At one extreme are processes involving the direct slushing of wastepapers with no additional processing, followed by conversion into coarse products such as construction papers, corrugating media and other coarse board stock. At the other extreme are mills using high quality wastepapers which subsequently are deinked by chemical means, screened, cleaned, and processed through multistage bleaching systems in a manner very similar to wood pulping. High quality deinking pulps are utilized in the production of fine quality tissue, printing, and business papers.

Fibers are purchased by nonintegrated mills, which manufacture a wide range of products. The products range from specialty board items through the highest quality fine papers.

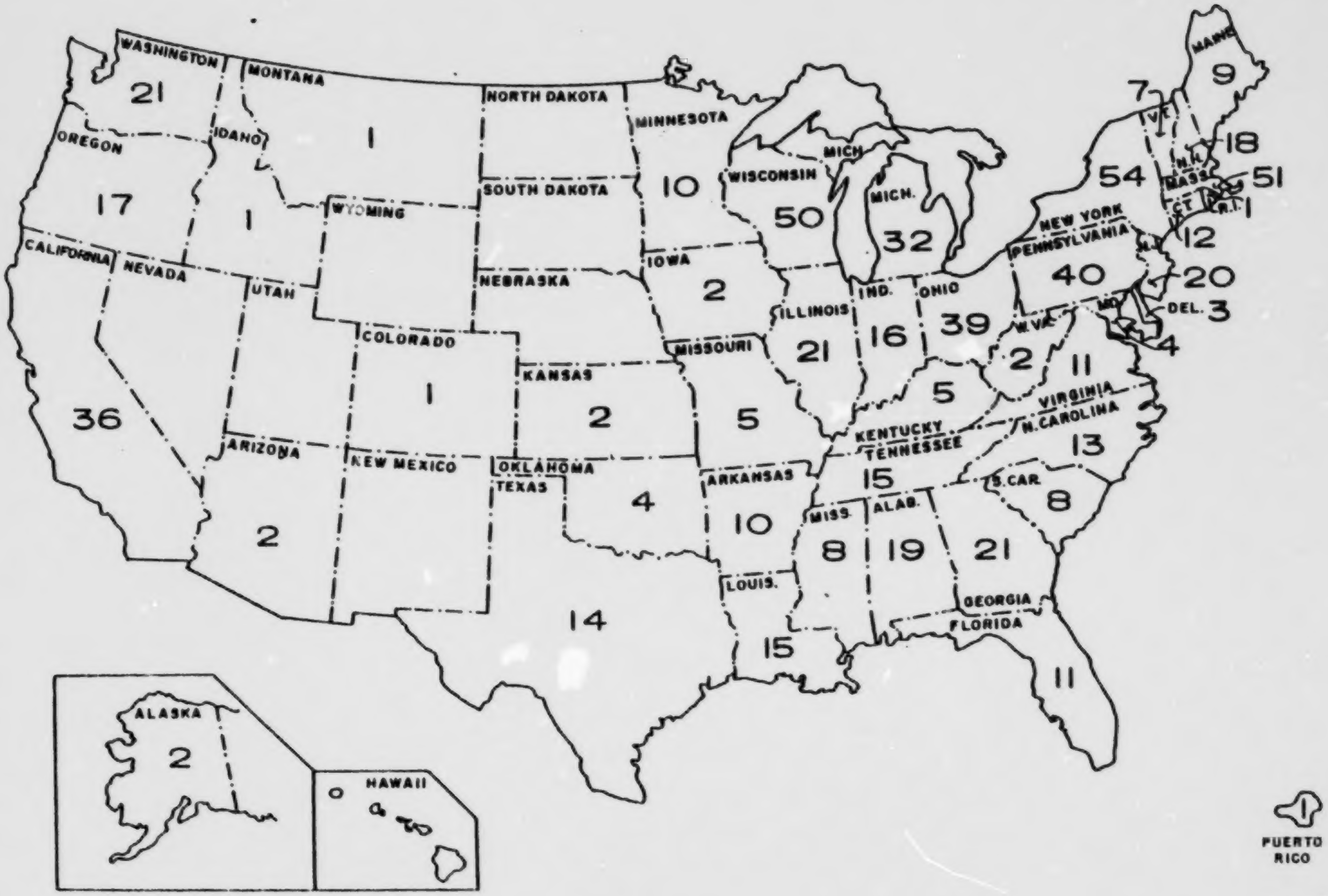
The U.S. pulp, paper, and paperboard industry is concentrated in the northeastern, southern, and western states as shown in Figure 1.

Other Wood Products Industries

The other wood products industries are diverse and are broken down in the following point source categories.

Veneer/Plywood --

In 1972 there were approximately 593 veneer plywood plants operating in the United States Of these, approximately 366 processed hardwood, and 227 processed softwood. Hardwood products are used for decorative purposes. Softwood products are used in structural applications.


WASHINGTON
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NEW MEXICO
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MINNESOTA
10
IOWA
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MISSOURI
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ARKANSAS
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LOUIS.
15
WISCONSIN
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MICH
MICH.
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ILLINOIS
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IND.
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OHIO
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KENTUCKY
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TENNESSEE
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HAWAII
PUERTO RICO
1

Figure 1. Pulp, paper, and paperboard mills in the United States.

The typical hardwood plywood plant is a small, privately-owned mill producing 5 to 10 million ft^2 of product per year. This is in contrast to the production pattern in the softwood plywood section, which is typified by a mill with a 100 to 125 million ft^2 output per year. Furthermore, softwood plywood plants tend to be multiplant operations owned by a broad-based forest products company. Figures 2 and 3 present the density of hardwood and softwood mills across the United States.

Particleboard --

The particleboard industry consists of approximately 74 plants. Producers range from large multi-forest product companies producing particleboard from their wood wastes, to relatively small furniture companies producing particleboard for captive consumption. The largest four firms control approximately 36 percent of the industry capacity.

Particleboards are board products which differ from conventional fiberboards in that they are composed of distinct particles of wood or other ligno-cellulosic materials which are bonded together with an organic binder. The "particles" vary in size and must be distinguished from the fibers used in insulation and hardboard. Other terms used for particleboard include chipboard, flakeboard, silverboard, shaving board, and wood waste board. Figure 4 shows the distribution of particleboard manufacturing facilities across the United States.

Millwork --

The millwork industry manufactures molding, doors and windows, and cabinetry. The industry is quite fractionated with the eight largest companies producing only 13 percent of the output in 1970.(1) Among producers of molding, which accounts for 20 percent of the industry output, 35 companies possess approximately 80 percent of the capacity.(1)

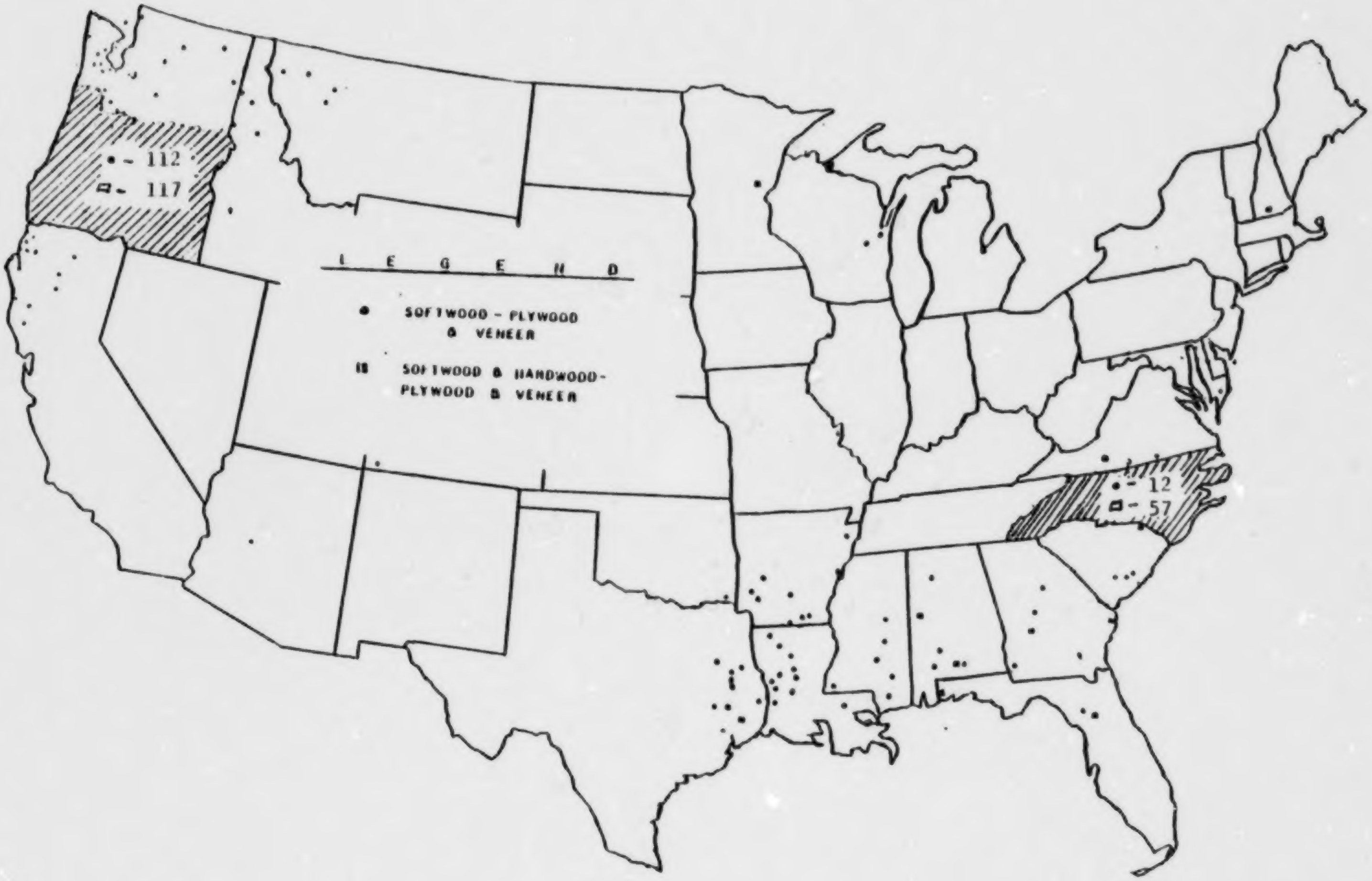
Some molding companies are integrated with sawmills, although most are separate. Local producers of windows, doors, and cabinetry are usually small operations. The total number of plants is not well-documented. Figure 5 presents the distribution of mills across the United States in 1967. The number of mills in each state include any mills primarily involved in mill work production.

Structural Wood Members --

In 1972, 642 firms were actively engaged in the manufacture of structural wood members and were reported to be operating 678 establishments. The industry is quite diverse, with the top 50 companies supplying only 46 percent of the total shipments.(1) This industry is primarily engaged in the manufacture of laminated or fabricated trusses, arches, and other structural members of lumber.

Wood Furniture and Fixtures --

The large number of products included in this group prohibits a listing of each. The processes involved include the machining and fabrication (fastening or gluing) of primary forest products such as lumber, plywood, and board. Figure 6 shows the concentration of mills by state.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LEGEND
• SOFTWOOD - PLYWOOD & VENEER
▫ SOFTWOOD & HARDWOOD-PLYWOOD & VENEER
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Figure 2. Distribution of softwood veneer and plywood mills throughout the United States. (2)

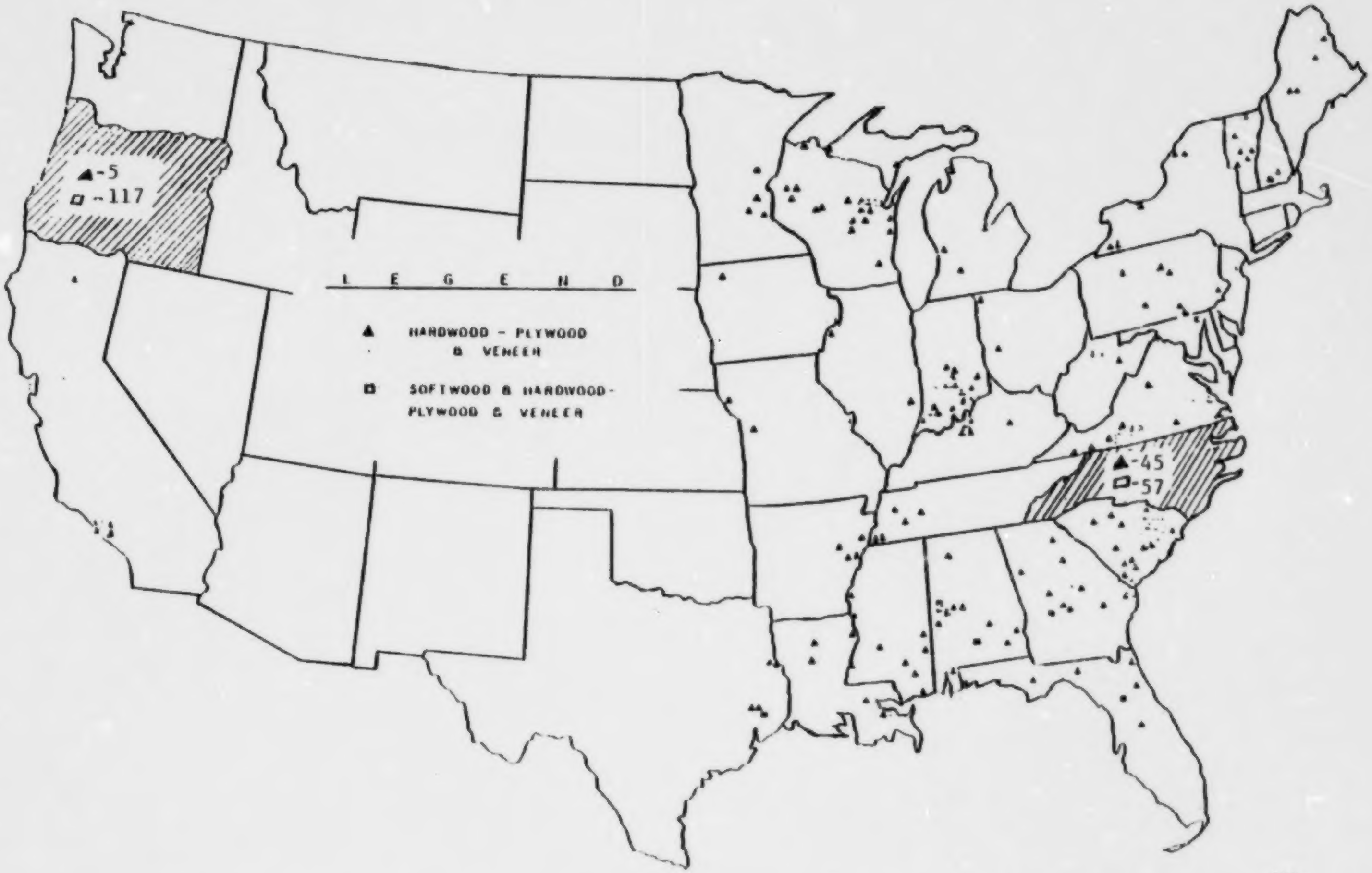
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Figure 3. Distribution of hardwood veneer and plywood mills throughout the United States. (2)

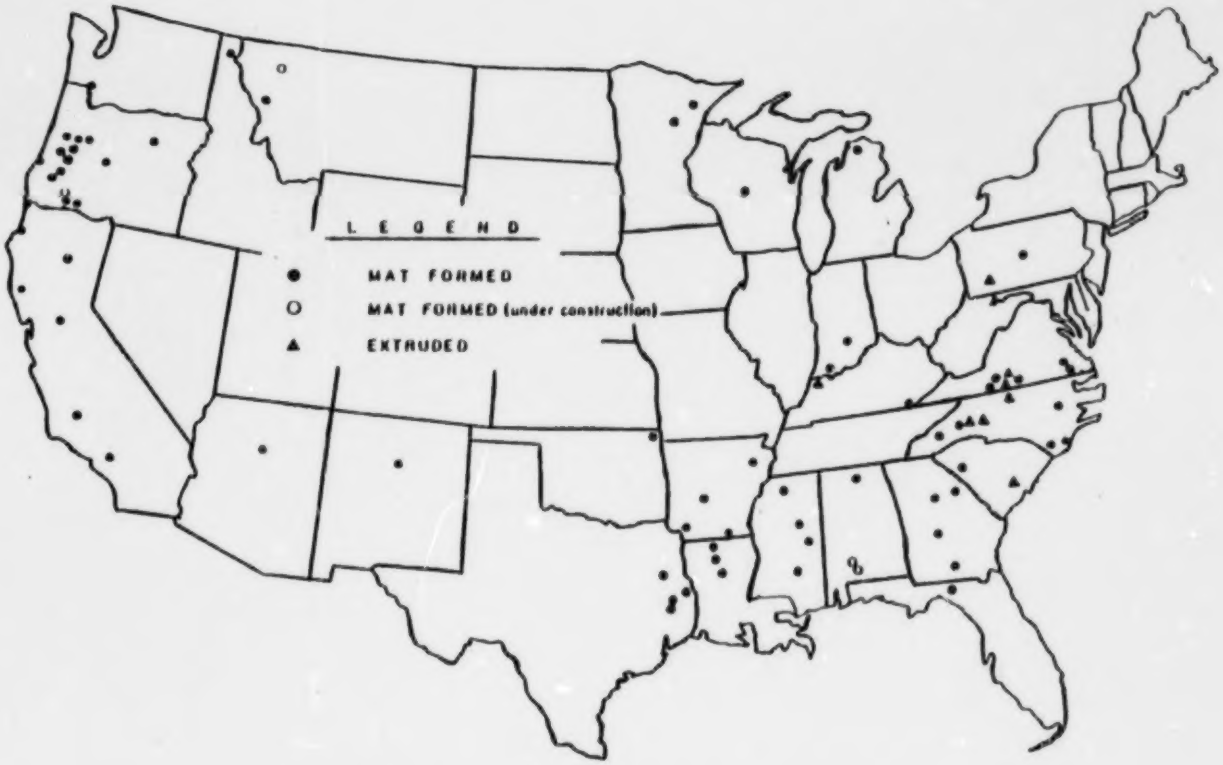
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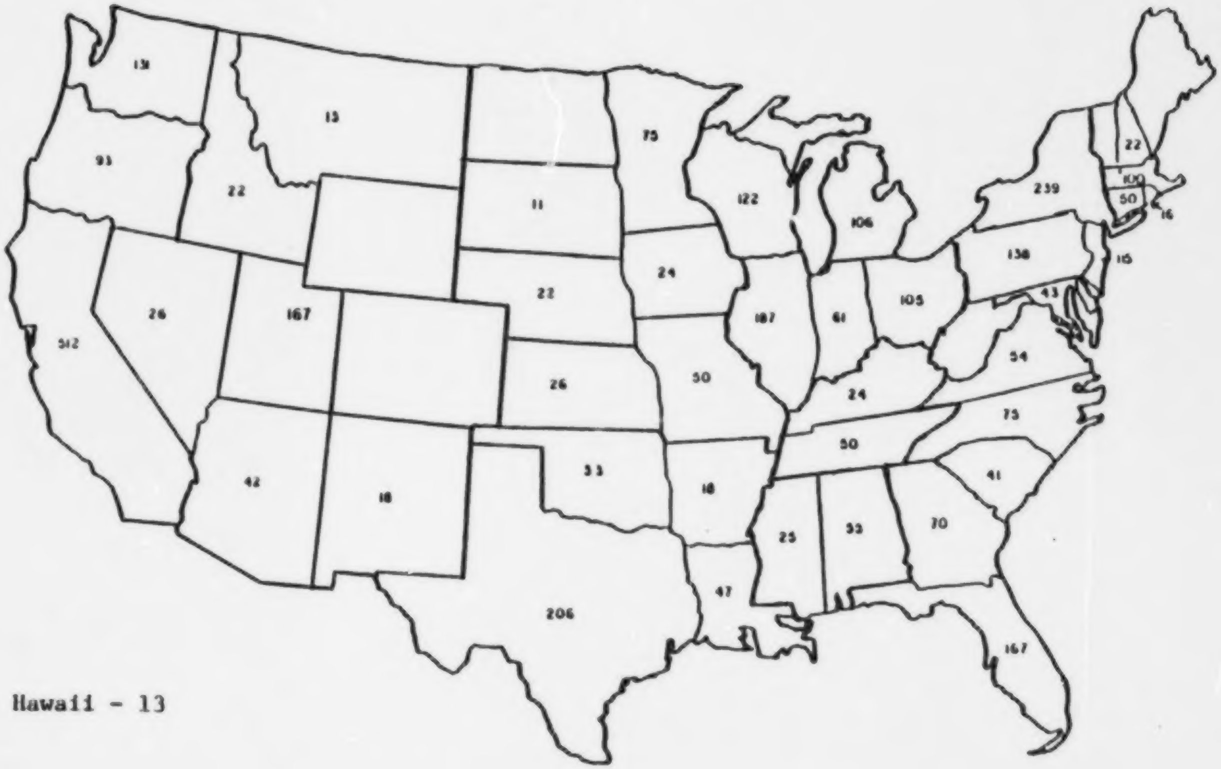
Figure 4. Particleboard manufacturing facilities. (184)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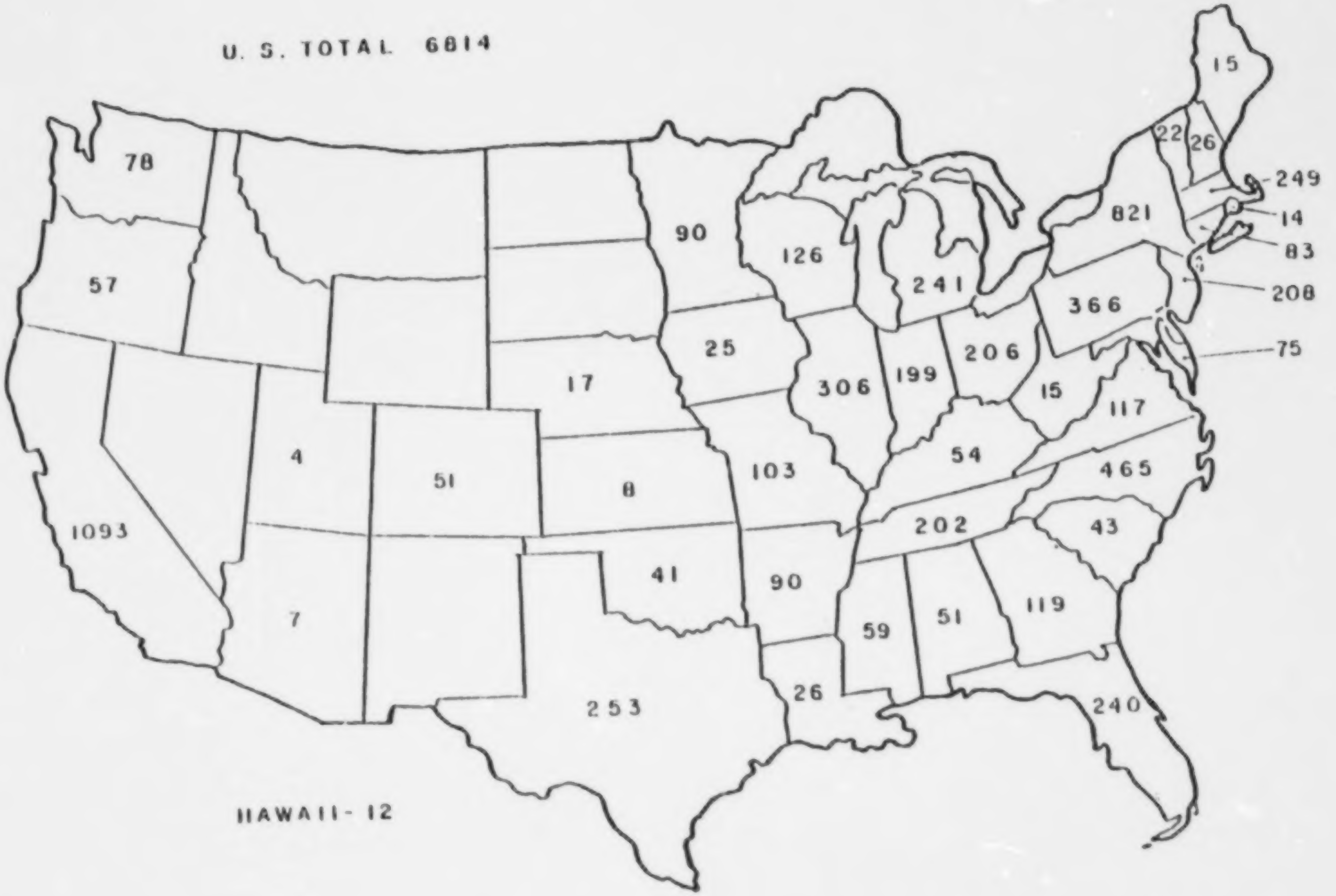
167

Hawaii - 13

Figure 5. Millwork plants. (184)


U. S. TOTAL 6814
15
22
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465
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119
51
59
7
253
26
240
HAWAII- 12

Figure 6. Furniture and fixture plants. (184)

Gum and Wood Chemicals --

Major products from this industry include: wood turpentine, wood rosin. tall oil, fatty acids, gum rosin, gum turpentine, and pure oil. Twelve major companies account for the majority of production in this industry. The more efficient use of rosin for sizing in the paper industry and decline in the use of gum for naval stores indicate a downward trend for this industry in the future.

Wood Preserving --

There are approximately 415 companies engaged in wood preserving in the United States. Fifty percent of the industry capacity is controlled by ten companies. Over three-quarters of the plants are concentrated in two distinct regions. One area extends from east Texas to Maryland and corresponds roughly to the natural range of southern pines, the major species utilized. The second, smaller area is located along the Pacific Coast, where Douglas fir and western red cedar are the predominant species. Figure 7 depicts the location of the wood preserving plants in the United States.

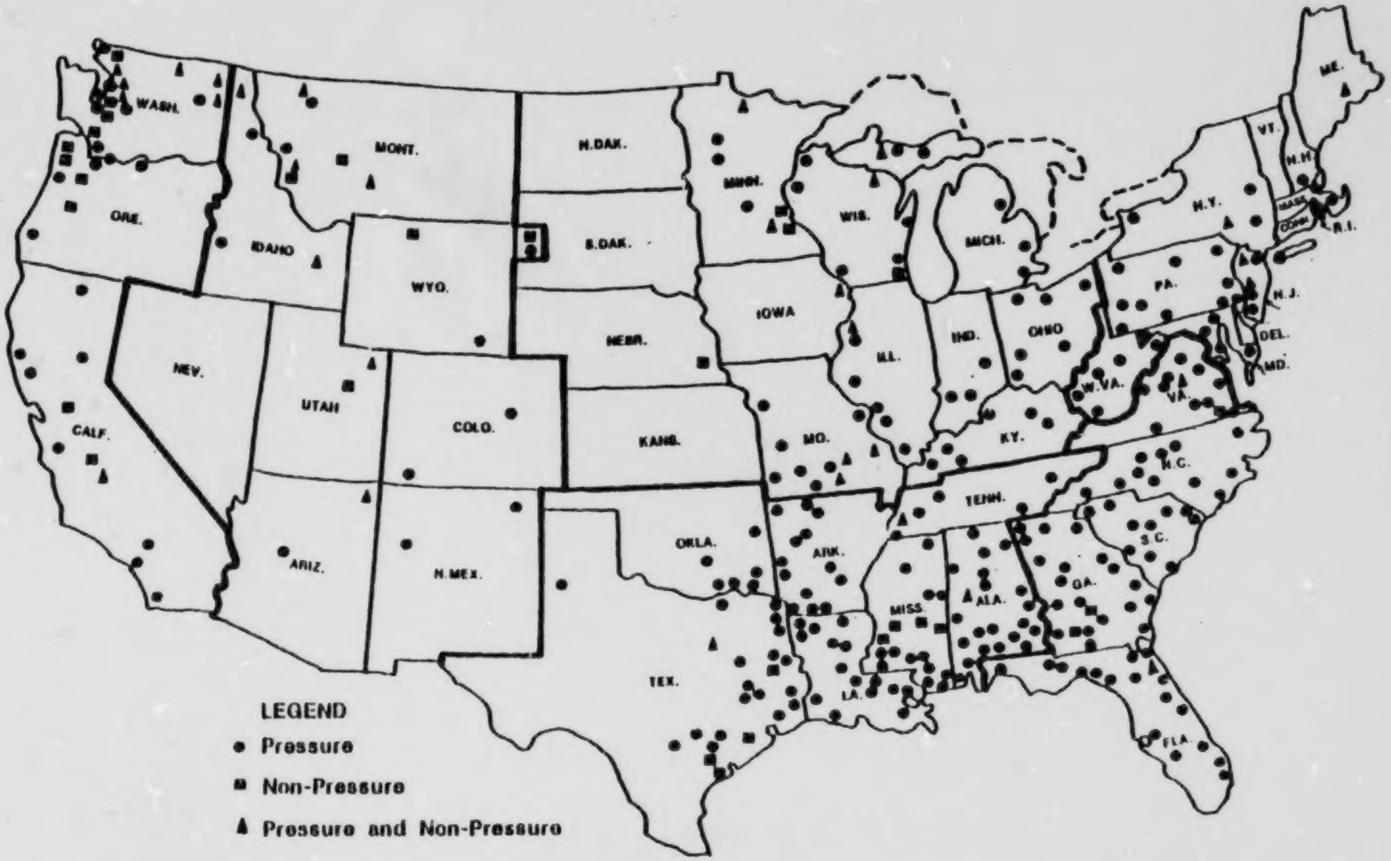
The wood preserving industry applies chemical treatment to round or sawn wood products for the purpose of imparting insecticidal, fungicidal, or fire resistant properties to the wood. The three most prevalent types of preservatives used in wood preserving are creosote, pentachlorophenol (PCP), and various formulations of water-soluble inorganic chemicals, the most common of which are the salts of copper, chromium, and arsenic. Fire retardants are formulations of salts, the principal ones being borates, phosphates, and ammonium compounds. Eighty percent of the plants in the United States use at least two of the three types of preservatives. Many plants treat with one or two preservatives plus a fire retardant.

Insulation Board --

There are 16 plants in this subcategory that use wood as the predominant raw material. Insulation board is a form of fiberboard, which in turn is a broad generic term applied to sheet materials constructed from ligno-cellulosic fibers. Insulation board is a "non-compressed" fiberboard, which is differentiated from "compressed" fiberboards, such as hardboard, on the basis of density. Densities of insulation board range from about 0.15 to a maximum 0.50 g/cu cm (9.5 to 31 lb/cu ft).(6) Figure 8 shows the geographical distribution of insulation board mills in the United States.

Hardboard --

There are 16 wet process hardboard mills across the United States as shown in Figure 9. Hardboard is a form of fiberboard, which is a broad generic term applied to sheet materials constructed from ligno-cellulosic fibers. Hardboard is a "compressed" fiberboard, with a density over 0.50 g/cu cm (31 lb/cu ft). The thickness of hardboard products ranges between 2 and 13 mm (nominal 1/12 to 7/16 in.).(6)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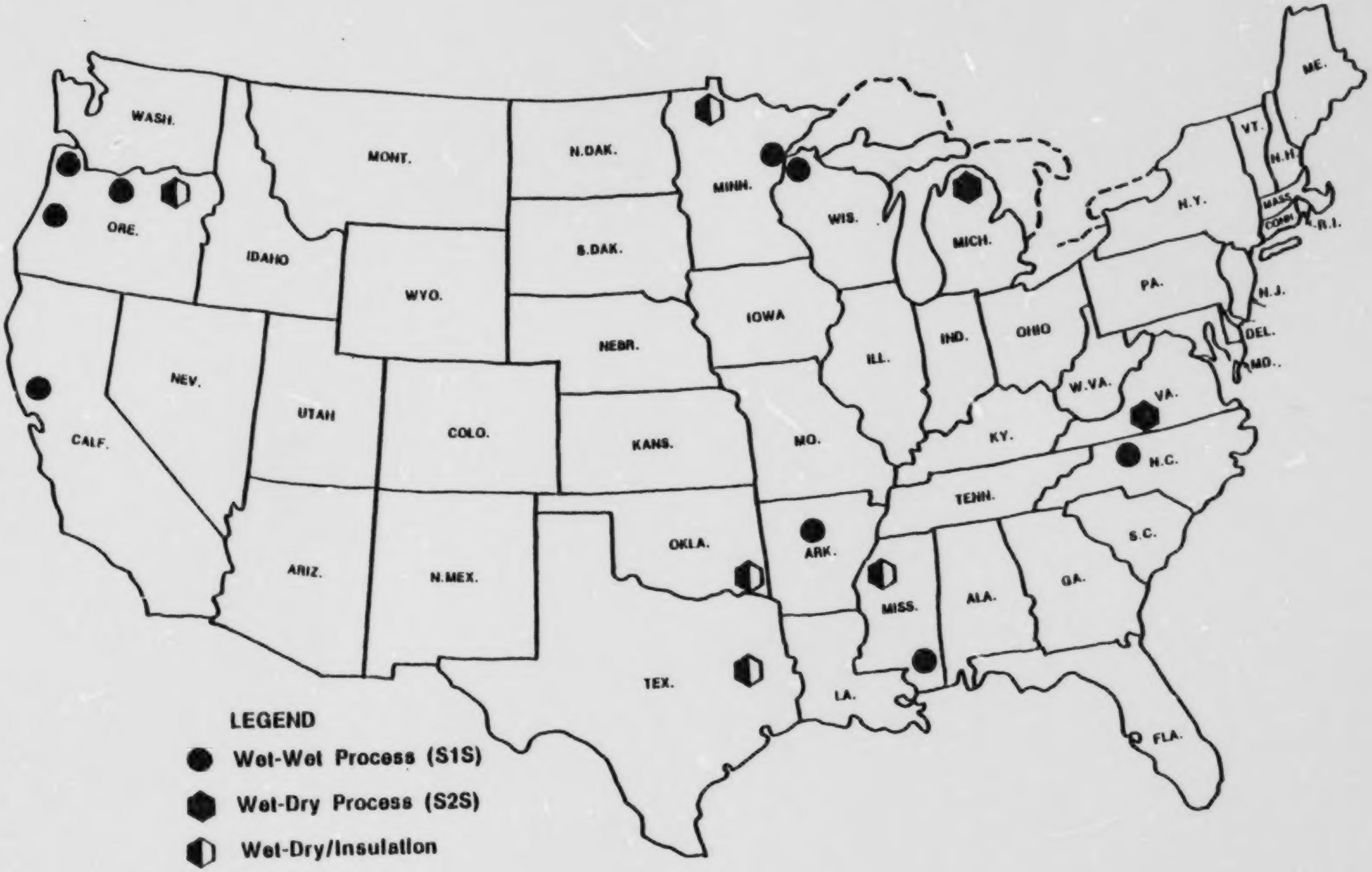
VA.
W.VA.
PA.
N.Y.
VT.
N.H.
ME.
MASS.
CONN.
R.I.
N.J.
DEL.
MD.
LEGEND
● Pressure
■ Non-Pressure
▲ Pressure and Non-Pressure

Figure 7. Geographical distribution of wood preserving plants in the United States. (2)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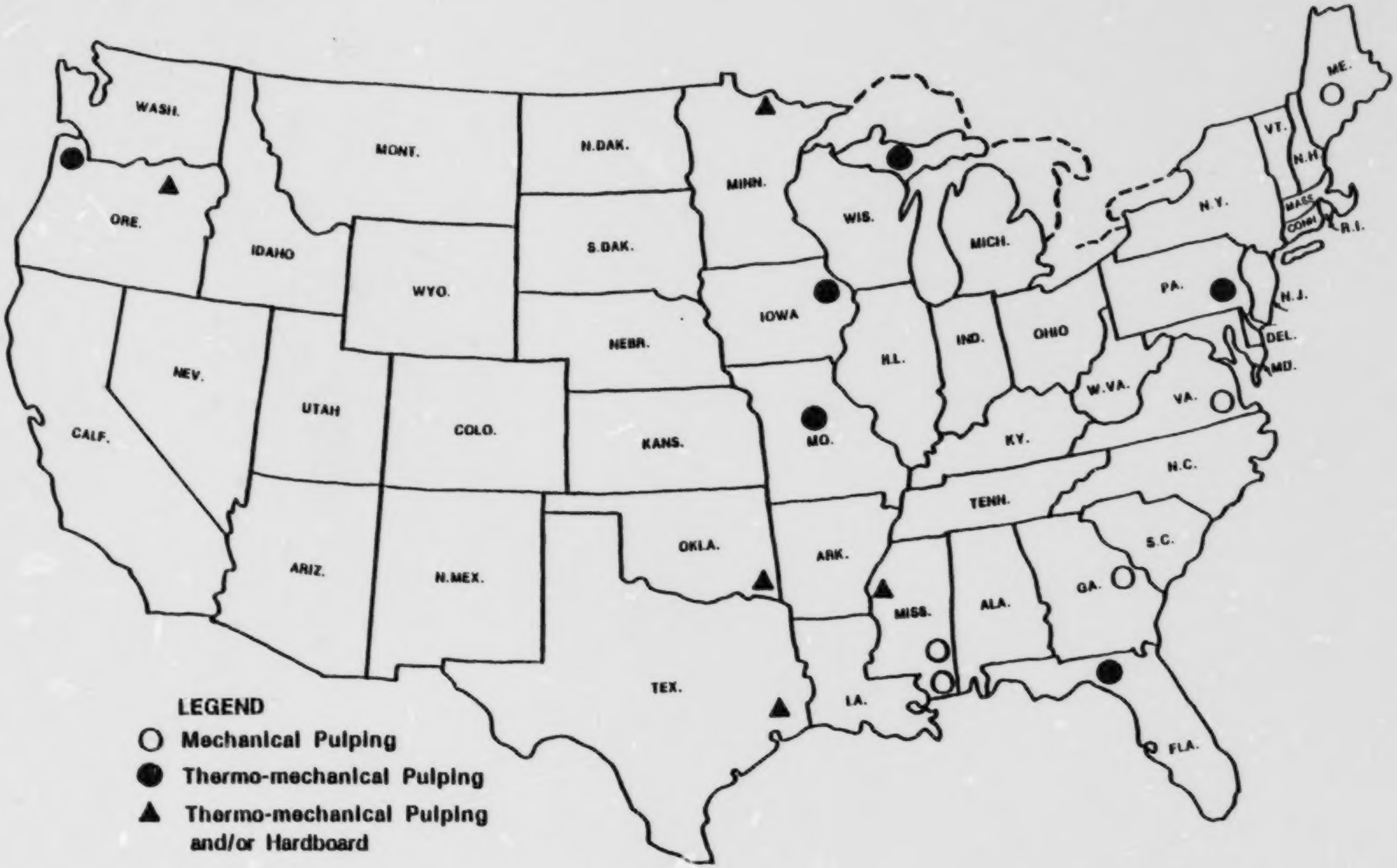
DEL.
MD.
VT.
N.H.
ME.
MASS.
CONN.
R.I.
LEGEND
● Wet-Wet Process (S1S)
⬢ Wet-Dry Process (S2S)
◐ Wet-Dry/Insulation

(6)

Figure 8. Geographical distribution of insulation board manufacturing facilities in the United States.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N.J.
DEL.
MD.
VT.
N.H.
MASS.
CONN.
R.I.
ME.
LEGEND
○ Mechanical Pulping
● Thermo-mechanical Pulping
▲ Thermo-mechanical Pulping and/or Hardboard

Figure 9. Geographical distribution of hardwood manufacturing facilities in the United States.(6)

Summary of Wood Products Industries

Wood products industries have a number of subcategories as shown in Table 1. The approximate number of plants and typical production capacities for each subcategory are also noted. Descriptions of industries follow.

PRODUCTION TRENDS

Pulp, Paper and Paperboard

Pulp, paper, and paperboard production capacity have exhibited moderate but steady growth in recent years. This pattern is illustrated in Tables 2 and 3, for 1975 through 1981.(3)

Other Wood Products

Other wood products industry production patterns are shown in Tables 4 through 9.(4,5,6) Lumber production has fluctuated with no trend in recent years. Particleboard production peaked in 1973 and then began declining. Hardwood plywood production steadily declined, while prefinished hardwood plywood made from purchased pulp increased dramatically over the past decade. Softwood plywood production experienced steady gains over the same period (Tables 7, 8, 9).

POLLUTION ABATEMENT COSTS

According to an advance report from the U.S. Department of Commerce, Bureau of the Census, United States manufacturing establishments spent $3.586 billion on pollution control in 1977.(7) This total represents a 2 percent increase over 1976 capital expenditures. Operating costs for pollution abatement totaled $5.485 billion in 1977, representing a 21 percent increase over the 1976 total of $4.539 billion. Costs incurred by the lumber and wood products industry (SIC 24) and the paper and allied products industry (SIC 26) are summarized in Table 10.

Table 10 shows there was a slight reduction in capital expenditures for pollution control by the paper and allied products industry in 1977. This indicates that many mills have already completed the construction of required environmental control systems. Pollution control operating costs rose by 28 percent for the paper and allied products industry from 1976 to 1977. Most of the costs incurred relate to air and water pollution control efforts.

TABLE 1. WOOD PRODUCTS INDUSTRY SUBCATEGORIES PROFILE

Subcategory*	Number of plants	Typical Mill production (tons/day)	Products
Pulp, Paper and Paperboard Industry			
Dissolving kraft	3	1,000	Pulp
Market bleached kraft	12	600	Pulp
BCT bleached kraft**	9	800	BCT paper
Alkaline fine	20	900	Printing paper
Unbleached kraft (linerboard)	20	1,000	Linerboard
Unbleached kraft (bag)	8	1,000	Bag
Semi-chemical	20	425	Corrugating medium
Alkaline unbleached and semi-chemical	10	1,500	Linerboard corrugating medium
Dissolving sulfite	6	600	Pulp
Papergrade sulfite	15	450	Tissue & writing paper
Groundwood thermo-mechanical pulp	4	300	Groundwood specialty
Groundwood CMN papers#	5	600	Newsprint
Groundwood fine papers	9	500	Printing paper
Deink (fine)	5	180	Fine paper
Deink (newsprint)	6	400	Newsprint
Deink (tissue)	15	180	Tissue paper
Tissue from wastepaper	23	40	Industrial tissue
Paperboard from Wastepaper	159	160	Wastepaper board
Wastepaper molded products	18	50	Molded products
Builders' paper and roofing felt	66	100	Roofing & construction
Nonintegrated fine	45	215	Printing paper
Nonintegrated tissue	28	180	Sanitary tissue
Nonintegrated lightweight	18	60	Lightweight & thin paper
Nonintegrated filter & nonwoven	14	20	Filter paper
Nonintegrated paperboard	16	40	Board & coarse paper

TABLE 1 (Continued)

Subcategory*	Number of plants	Typical Mill production (tons/day)	Products
Other Wood Products Industries			
Veneer/plywood	593	55	Veneer/plywood
Particleboard	75	60	Particleboard
Millwork	35†	630	Windows/doors
Structural members	678	10	Structural members
Wood furniture & fixture	N.D.	340,000§	Furniture & fixtures
Gum & wood chemicals	130	500§	
Char & Charcoal Briquets	77		Char & Charcoal briquets
Gum Rosin & Turpentine	7		Gum rosin & turpentine
Wood Rosin, Turpentine & Pine Oil	5		Wood rosin & turpentine
Tall Oil Rosin, Fatty Acids, & Pitch	12		Tall oil rosin
Essential Oils	9		Cedarwood oil
Rosin Derivatives	13		Rosin derivatives
Sulfate Turpentine	7		Turpentine
Wood preserving	300	--	Treated lumber
Waterbourne or Non-Pressure			
Steam			
Boultonizing			
Insulation Board	16	334	Insulation board
Hardboard	33	--	Interior wall paneling, furniture
Dry process	17		
Wet process (S1S)	9		
Wet process (S2S)	7		

*Note: Pulp, paper, and paperboard industry profile was derived from mill survey data collected through ongoing effluent guidelines development. Other wood products profile information was obtained from Battelle Columbus Laboratory's study effort; wood preserving industry data were obtained from reference 2.

**BCT = Paperboard, coarse, tissue.

#CMN = Course, molded and news.

†Major producers of molding only.

§Total production for this industry.

TABLE 2. PULP, PAPER AND PAPERBOARD INDUSTRY WOODPULP PRODUCTION CAPACITY: 1977-1981

	Amount produced in thousands of short tons				
Grades	1977	1978	1979	1980	1981*
Total Wood Pulp#	51,849	52,998	54,150	55,613	56,963
Dissolving	1,648	1,639	1,613	1,611	1,611
Sulphite paper grades	2,252	2,096	2,066	2,000	2,000
Sulphate and soda paper grades	36,922	38,016	38,909	39,893	40,911
Bleached	15,822	16,678	17,267	18,114	18,438
Semi-bleached	1,547	1,538	1,552	1,552	1,552
Unbleached	19,552	19,801	20,090	20,227	20,921
Semichemical	4,514	4,602	4,691	4,795	4,845
Mechanical#	6,442	6,573	6,801	7,242	7,524
For paper & paperboard	4,502	4,623	4,827	5,267	5,549
For other paper and board#	1,939	1,949	1,974	1,975	1,975
Screenings	71	71	71	71	71
Total machine dried wood pulp	7,975	8,280	8,707	8,972	9,171
Dissolving	1,648	1,639	1,613	1,611	1,611
Bleached sulphite	638	578	563	496	496
Bleached sulphate	5,311	5,720	6,198	6,528	6,724
Unbleached sulphate	178	130	126	126	126
All other	200	213	207	211	214

*Capacity additions presented here for 1981 include only presently known commitments and do not necessarily represent final expansion plans of the industry for that year.

#Excludes 2.5 million tons of defibrated pulp capacity used to produce furnish for hard pressed board.

Source: American Paper Institute(3)

TABLE 3. PAPER AND PAPERBOARD PRODUCTION CAPACITY: 1977-1981

Grades	Amount produced in thousands of short tons				
	1977	1978	1979	1980	1981*
Total, all grades paper and paperboard#	66,459	67,505	69,355	71,233	72,579
Total paper	29,831	30,389	31,059	32,417	32,964
Newsprint	4,069	4,115	4,259	4,742	4,973
Printing, writing & related	14,975	15,401	15,684	16,340	16,561
Uncoated groundwood	1,367	1,367	1,378	1,360	1,361
Coated groundwood	2,408	2,429	2,461	2,653	2,788
Coated free sheet	1,989	2,056	2,125	2,169	2,224
Uncoated free sheet	7,464	7,775	7,924	8,350	8,380
Cotton fiber	133	131	131	131	131
Thin papers	402	416	424	431	432
Solid bleached bristols	1,213	1,226	1,240	1,245	1,245
Packaging and industrial converting†	6,242	6,220	6,246	6,246	6,271
Unbleached kraft†	4,317	4,372	4,397	4,400	4,431
Bleached packaging & industrial converting	1,069	973	964	965	961
Special industrial	856	875	884	881	879
Tissue	4,545	4,654	4,871	5,088	5,159
TOTAL PAPERBOARD	32,173	32,644	33,796	34,321	35,119
Unbleached kraft	14,793	15,081	15,659	15,827	16,535
	13,586	13,846	14,398	14,398	15,097
Solid bleached	4,020	4,154	4,289	4,362	4,396
Semichemical	4,661	4,762	5,057	5,155	5,158
Recycled	8,699	8,647	8,792	8,977	9,029
Total Construction Paper and Board and Other§	4,455	4,472	4,500	4,495	4,496

*Capacity additions presented here for 1981 include only presently known commitments and do not necessarily represent final expansion plans of the industry for that year.

#Excludes hard pressed board capacity; includes 170,000 tons of capacity for unbleached kraft paper facilities that have been shut down.

†Includes 170,000 tons of capacity for unbleached kraft paper facilities that have been shut down.

§Excludes hard pressed board capacity.

Source: American Paper Institute(3)

TABLE 4. TRENDS IN LUMBER AND PARTICLEBOARD PRODUCTION CAPACITY*

Year	Lumber (board-ftx10^6)	Particleboard (3/4-inch, ft^{2}x10^6)
1970	34,668	1,763
1971	36,998	2,394
1972	37,745	3,116
1973	38,595	3,493
1974	34,608	3,103
1975	32,619	2,367
1976	36,905	N.A.

*Source: U.S. Department of Commerce, Bureau(4)
N.A. = Not available

TABLE 5. HARDWOOD PLYWOOD AND PREFINISHED HARDWOOD PLYWOOD PRODUCTION: 1966-1977

	Hardwood plywood quantity ($ft^2 x 10^6$ surface measure)				Prefinished hardwood plywood made from purchased plywood#	
Year	Total	Shipped as unfinished	Shipped as prefinished*	Value (in millions)	Quantity ($ft^2 x 10^6$ surface measure)	Value (in millions)
1977	1,339.1	859.4	479.7	$468.2	2,190.2	$335.9
1976	1,250.8†	734.2†	516.6†	416.5†	2,091.0†	293.6
1975	1,148.3	649.2	499.1	347.2	1,861.7	242.1
1974	1,447.8	726.9	720.9	393.6	2,051.2	263.4
1973	1,810.2	864.1	946.1	409.4	2,453.3	313.9
1972	1,954.3	782.7	1,171.6	371.8	2,996.1	299.5
1971	1,813.7	913.5	895.2	326.7	2,202.4	214.7
1970	1,615.4	811.0	804.4	309.7	1,930.1	177.1
1969	1,644.8	857.6	791.2	347.0	1,811.9	180.2
1968	1,786.3	863.1	918.2	353.9	1,413.7	143.7
1967	1,693.3	934.5	758.8	327.7	902.9	98.0
1966	1,776.2	1,037.4	738.8	355.9	676.0	81.6

*"Shipped as prefinished" reflects hardwood plywood produced and prefinished at the same location.

#Data for "prefinishers" is not directly comparable with information published prior to 1972. In 1972, 16 establishments accounting for approximately 10 to 15 percent of the shipments value were added to the survey. Information for prior periods is not available.

†Revised by 5 percent or more.

Source: U.S. Department of Commerce(4)

TABLE 6. SOFTWOOD PLYWOOD PRODUCTION: 1967-1976[*]

Period Covered	Total Produced[†]		Amount produced by type			
			Interior		Exterior	
	Quantity[±]	Value (in millions)	Quantity[±]	Value (in millions)	Quantity[±]	Value (in millions)
1976	18,033.0	$2,541.9	5,264.6	$639.2	12,768.4	$1,902.7
1975	15,708.1	1,725.6	4,665.0	481.7	11,043.1	1,243.9
1974	15,507.9	1,625.8	4,730.3	463.9	10,777.6	1,161.9
1973	17,897.6	1,927.5	5,979.3	593.1	11,918.3	1,334.4
1972	17,974.6	1,665.8	6,343.0	545.2	11,631.6	1,120.6
1971	16,408.1	1,243.8	6,452.6	454.6	9,955.5	789.2
1970	14,126.7	958.4	5,870.8	371.0	8,255.9	587.4
1969	13,405.5	1,086.0	6,004.1	446.6	7,401.4	639.4
1968	14,516.4	1,069.5	7,141.0	479.8	7,375.4	589.7
1967	12,914.8	776.9	6,919.0	387.3	5,995.8	389.6

[†] Details do not add to total because of independent rourding.

[*] Source: U.S. Department of Commerce(4)

[±] Quantity in million square feet, 3/8 inch basis

TABLE 7. GUM AND WOOD CHEMICALS PRODUCTION, 1975

Item	Production	
	Volume	Weight (tons)
Rosin:		
Gum	69,600 drums	17,991
Steam distilled (wood)	328,480 drums	85,404
Tall oil	612,350 drums	159,211
Total	1,010,430 drums	262,606
Turpentine:		
Gum	20,240 50-gal bbl	3,632
Steam distilled (wood)	38,260 50-gal bbl	6,866
Sulfate	370,970 50-gal bbl	66,572
Total	429,470 50-gal bbl	77,070
Tall oil	--	614,224*
Tall oil fatty acids	--	146,638#

*Production in 1973 was 793,150 tons, and 726,475 tons in 1974.

#Production in 1974 was 181,608 tons.

Sources: Naval stores, U.S. Department of Agriculture Monthly Reports. 1975. Pulp Chemicals Association. New York, New York. January 23, 1976. Pulp Chemicals Association. New York, New York. April 16, 1976.

TABLE 8. MILLWORK AND STRUCTURAL WOOD MEMBERS PRODUCTION

Material consumed*	Production (in thousands of tons) Millwork	Structural wood members
Rough lumber	1,687.0	226.5
Dressed lumber	2,469.4	1,043.4
Softwood plywood	48.8	23.5
Thermosetting resins	--	4.3
Hardwood veneer#	298.8	--
Hardwood plywood#	116.4	--
Particleboard	124.6	
Hardboard	70.2	
Other materials	3,267.9	955.3
Total	8,083.1	2,253.0

*Excludes builders hardware.

#Assumes that reported surface areas are 1/4-in. thick.

Source: U.S. Department of Commerce(5)

TABLE 9. PRESERVED WOOD PRODUCT PRODUCTION, 1969-1973

Material	Amount produced (in thousands of m^3)				
	1969	1970	1971	1972	1973
Cross-ties	2,020	2,248	2,465	2,432	1,915
Switch-ties	180	223	176	169	142
Piling	417	428	388	406	368
Poles	2,107	2,174	2,106	2,111	2,135
Cross-arms	91.9	97.8	87.1	70.4	73.4
Lumber & timbers	1,689	1,577	1,695	1,811	1,950
Fence posts	443	428	472	515	430
Other	231	195	218	205	194
Total*	7,178.9	7,370.8	7,607.1	7,719.4	7,207.4

*Components may not add due to rounding.

Source: Environmental Science and Engineering, Inc.(6)

TABLE 10. POLLUTION ABATEMENT CAPITAL EXPENDITURES AND OPERATING COSTS, 1977 AND 1976 ($1,000,000)

		Pollution abatement capital expenditures (PACE)				Pollution abatement gross annual costs (PAGAC)			Percent change		
Industry	Year	Air	Water	Solid Waste	Total	Air	Water	Solid Waste	PACE	GAC	Total
Lumber and wood products	1977	34	19	7	60	20	19	34	+15	-11	73
	1976	30	9	13	52	27	21	34			81
Paper and allied products	1977	136	261	31	428	134	324	92	-12	+28	550
	1976	181	279	27	487	124	239	67			430

Source: U.S. Department of Commerce(7)

SECTION 2

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

WATER POLLUTION

Water pollution abatement legislation has resulted in the establishment of effluent limitations guidelines based on best practicable control technology currently available (BPCTCA). These guidelines primarily address conventional pollutants, including 5-day biochemical oxygen demand (BOD_5), total suspended solids (TSS) and pH. In addition, guidelines based on best available technology economically achievable (BATEA) and best conventional pollutant control technology (BCPCT) are currently being established to address conventional, priority (toxic), and nonconventional (neither conventional nor toxic) pollutants.

Conventional Pollutants

Pulp, Paper, and Paperboard Industry--

Annual average discharge information for calendar year 1976 indicates that at least one pulp and paper mill in each industry subcategory was meeting the BPCTCA guidelines which went into effect in July 1977. The sampling period reflected a time of construction and/or startup of many effluent treatment facilities. Therefore, it is expected that many more mills are currently meeting the BPCTCA guidelines.

Primary/biological effluent treatment is widely used in the wood products industry. These systems achieve approximately 80 percent removal of BOD_5 and TSS prior to discharge. Various additional effluent treatment systems may be installed to further reduce conventional pollutants. Chemical clarification, for example, may serve as a tertiary treatment after biological treatment. One such system has been successfully installed in a chemi-mechanical pulp and paper mill and is achieving annual average final effluent BOD_5 and TSS concentrations of 12 mg/l each. Specific studies are recommended to further establish optimum design characteristics for chemical clarification of various wood products effluents, and associated sludge production, costs, and other aspects of non-water quality impacts of the technology.

In many cases the installation of production process controls can reduce the flow and/or pollutant load to effluent treatment systems and the final discharge. Examples of these controls are spill collection systems to minimize the potential for shock loading, countercurrent pulp washing for flow reduction, and liquor evaporation for material and heat recovery as well as flow and pollutant reduction. The cost-effectiveness of production control alternatives should be carefully compared to that for effluent treatment technologies at specific facilities.

Conventional pollutants currently being discharged have been shown in two specific studies (8,9) to have minimal effects on receiving waters after mixing. This impact, however, is dependent in part on the relative flows of effluent and receiving water. A mill discharging to a small stream may have a greater impact than a similar discharge to a larger stream. Additional site-specific evaluations are needed to verify the magnitude of this phenomenon.

Existing effluent guidelines for TSS do not distinguish between settleable and nonsettleable solids. The impact associated with each, however, can vary. For example, settleable solids are more readily removed by treatment, while those not removed may tend to deposit on the stream bottom. This can have adverse impacts on water quality, benthic organisms, and stream aesthetics. Nonsettleable solids, on the other hand, are not easily removed by conventional treatment and tend to remain in suspension long after being discharged. As such, they can impact water quality far downstream of the mill. Additional data relating the actual magnitude of these impacts is needed.

Other Wood Products Industries--

Conventional pollutant discharges from other wood products industries are usually highly variable and less well-documented than those for the pulp and paper industry.

Nonconventional Pollutants

Nonconventional pollutants include any that are not specifically identified as conventional or priority pollutants in the current legislation. These include color, foam and a variety of wood-derived toxicants which were not included in the priority pollutant list.

Color can cause adverse aesthetic effects and can hinder light penetration in receiving waters, which can affect aquatic life. The major source of color in the pulp, paper and paperboard industry is the first caustic extraction stream in bleached kraft pulp mills. Several production process controls including alternative bleaching sequences and spill controls can reduce raw caustic extract color. Chemically assisted precipitation in addition to conventional and toxic pollutant reduction, can reduce final effluent color from 50 to 90 percent cost.(185)

Foam can produce adverse aesthetic effects in receiving waters. The situation is complicated by the fact that many compounds contributing to foam are believed to be wood-derived and occur naturally in many streams.

Toxic wood-derived compounds include resin and fatty acids such as abietic, dehydroabietic, isopimaric, pimaric, oleic, linoleic, and linolenic. Chlorinated analogues resulting from pulp bleaching include epoxystearic acid, dichlorostearic acid, monochloroabietic acid, dichloroabietic acid, trichloroguaiacol and tetrachloroguaiacol.

Due to their dependency on wood source, process controls and other variables, it is extremely difficult to formulate a predictive relation for toxic pollutants. Additional study is recommended in this area.

Priority and other toxic pollutants contribute to a limited but variable toxicity in many pulp and paper mill effluents. A major cause for concern over this toxicity is then very large effluent volumes. When discharged, these materials can have lethal and sublethal effects on aquatic life. Additional study is recommended to further establish the relative contribution of each compound to the toxicity of the wastes and possible synergistic effects.

Research is needed to identify the precise causes of foam. Many of these wood-derived compounds, such as resin acids, fatty acids and their chlorinated analogues, have also been shown to be major causes of the observed toxicity in pulp, paper and paperboard mill effluents. The foam separation process has been shown to effectively treat foam and toxicity, but has little effect on BOD_5 and TSS.

Priority (Toxic) Pollutants

Wood Products--

Priority (toxic) pollutants (49, 18 in wood preserving, also arsenic) known to be present in wood products industries waste include chloroform (from pulp bleaching); heavy metals (chromium, copper, lead, mercury and zinc) from papermaking additives and wood preserving; PCB's (from waste paper); and pentachlorophenols (PCP) and PNA's (from wood preserving).

Existing biological treatment has been shown to detoxify effluents between 60 and 80 percent of the time (10,11). Periods of toxic discharge have been associated with mill upsets.(10, 11) These toxicity reductions can be improved through the use of flow equalization and production process controls. The detoxification efficiency can be further enhanced by installing technologies such as foam separation, chemically assisted clarification, or carbon adsorption in addition to biological treatment.

Chemical coagulation of wood preserving wastes with 150 mg/l alum on a laboratory scale was shown to be capable of a 50 to 75 percent PCP reduction. This resulted in final effluent PCP concentrations of from 3 to 10 mg/l.(12)

Additional research is recommended to further establish the treatability of various wood product effluents, the optimum design parameters of applicable technologies; and the cost and other non-water-quality aspects for installing selected technologies.

Nonpoint Source Pollution

Nonpoint source pollutants from silvicultural activities include sediment (TSS) and its associated BOD5, nutrients, herbicides, rodenticides, and insecticides. These can impact the receiving waters nearby. Nutrients from fertilization can alter the trophic state of these waters. Proper management practices, including buffer strips adjacent to streams and the avoidance of direct chemical application to surface waters, can minimize adverse water quality impacts from nonpoint sources. Continued monitoring is recommended to ensure that these practices are being adhered to and that no significant adverse impacts occur.

AIR POLLUTION

Existing external air pollution control devices, in conjunction with internal process controls, can be effective in the reduction of air pollutants, especially particulates and sulfur dioxide. Air pollutants often limited by state governments include particulates and sulfur dioxide, as well as total reduced sulfur (TRS) compounds. Generally, southern states have stricter particulate standards, while northwestern states have stricter reduced sulfur compounds standards. The major impacts associated with these pollutants are odor problems and potential respiratory effects.

Pulp, Paper and Paperboard Industry

Pulp, paper and paperboard mill recovery furnace operations are those likely to be affected by stringent regulations. The initial kraft mill furnace designs did not seriously consider the control of reduced sulfur emissions. Particulate discharges from overloaded furnaces are great, and the sulfur dioxide emissions from sulfite mill recovery furnaces are often too high to meet the standards of some states. Secondary odor controls or replacement of the furnace are probable requirements for meeting state standards. In the case of odor, the sensitivity of the human nose to TRS is so high, that it is almost impossible to completely eliminate this impact.

The pulp, paper and paperboard industry, because it is a large offender, has done a significant amount of groundwork for the other wood products industries in the field of air pollution control. Hydrocarbon and carbon monoxide emissions of the veneer/plywood industry can be incinerated, and particulate emissions of the particleboard industry can be controlled by conventional pollution control devices. These are the same means of control used in the pulp and paper industry.

Air emissions from the wood preserving industry can exceed current air pollution regulations. The sources of emissions are: a dense plume of volitized organics when a pressure vessel is opened and the newly treated wood is removed and cooled; and particulate emissions from the vacuum exhaust, as well as in the exhaust during steam cleaning. A control technology to reduce the volitized organics is to reduce the temperature of the newly treated wood as it is removed from the pressure vessel. This is accomplished by the placement of spray nozzles just off the open end of the pressure vessel, to create a water blanket to cool the wood as it is slowly removed.

Outdated kraft mill recovery boilers are likely to be the major factor in mills not meeting state air pollution standards. Replacement of the boilers may be the only way to meet reduced sulfur compounds and particulates standards, but such replacement will be expensive. An economic analysis which would include a survey of furnaces needing replacement based on age and emissions, an estimate of replacement cost, and examination of the industry's ability to absorb the cost is suggested.

The use of cross-recovery systems in sulfite and NSSC mills may produce significant sulfur dioxide emissions. A study may be needed to evaluate the impact of these emissions and to evaluate the applicable control technologies. One technology that should be investigated is the use of regenerable stack gas desulfurization processes.

SOLID WASTES

Solid waste generation in the wood products industries consists primarily of wood wastes, wastewater treatment plant sludge and refuse generated by personnel activities. Although many wood wastes are burned for heat recovery, the most common means of sludge and refuse disposal at present is landfilling.

There is no consolidated information concerning the practices at the landfill sites for these wastes. Once the current evaluation efforts have resulted in classification of landfills in the U.S., it should be verified that the wastes from this industry are being placed in adequate sites.

If chemically assisted clarification were implemented on an industry-wide basis in the pulp, paper, and paperboard industry , it is estimated that wastewater treatment plant sludge production would increase by approximately 20 to 30 percent (dry solids basis). This sludge would probably be difficult to dewater and dispose of, and would have environmental and economic impacts. A study is needed to determine the magnitude thereof.

Additional investigation should be performed in the area of energy recovery from solid wastes (including sludges). The potential energy savings, economic cost, and air emissions must be balanced against the economic and environmental costs of landfilling. Also, alternate solid waste disposal and utilization technologies (such as composting) should be investigated further for use in the wood products industries.

SECTION 3

WATER POLLUTION CONTROL

INTRODUCTION

Water pollution sources in the wood products industries can be classified into two general categories: point sources and nonpoint sources. Most of the existing information and regulatory history has focused on point source discharges; e.g., direct discharges to receiving waters from outfall pipes or discrete channels. Most of the information presented in this section of the report relates to point source discharges. However, some concluding remarks at the end of this section address nonpoint sources and their impact.

This section begins with a summary of existing water pollution control regulations, followed by an introduction to the types and impacts of pollutants found in the pulp, paper, and paperboard industry and the other wood products industries. The section concludes with a summary of existing and available water pollution abatement technologies which can be applied to reduce the impact of pollutants generated by this industry.

WATER POLLUTION CONTROL REGULATIONS

Effluent Discharge Regulations

The major federal legislation affecting industrial effluent quality is the Federal Water Pollution Control Act Amendments of 1972 (PL 92-500). Significant portions of the 1972 Act require the attainment of effluent quality reflecting best practicable control technology currently available (BPCTCA) by July 1, 1977. Effluent quality reflecting best available technology economically achievable (BATEA) would be attained by July 1, 1983.

The Clean Water Act of 1977 (PL 95-217), which has superseded PL 92-500, allows EPA to extend the 1977 deadline for BPCTCA to January 1, 1979, if an industry has acted accordingly. The BATEA guidelines were divided into three subcategories in the 1977 law: 1.) priority (toxic) pollutants; 2.) conventional pollutants; and 3.) nonconventional pollutants, i.e., all pollutants which are not considered conventional or priority pollutants (e.g., color). Also, EPA must allow a waiver of the conventional pollutant BATEA guidelines if the costs do not bear a reasonable relationship to the associated benefits.

Achievement of BATEA guidelines for nonconventional pollutants was postponed by the 1977 Clean Water Act to July 1, 1984. Waivers may be obtained if the industry can demonstrate to EPA's satisfaction that the discharge will not interfere with the highest degree of water quality. Any pollutant currently considered nonconventional can be placed on the toxic list by EPA.

Toxic pollutants consist of a list of 129 chemicals (priority pollutants) resulting from a consent decree (NRDC vs. Train and consolidated cases, U.S. District Court, D.C., June 9, 1976, 6ELR20588). EPA must set discharge standards for priority pollutants by July 1, 1980, and industries must comply by July 1, 1984. No waiver is possible for toxic pollutants. Also, EPA can set more stringent toxic standards, including zero discharge, at its discretion. EPA can also require industry to follow in-plant best management practices for the control of toxic and hazardous pollutants under the 1977 Clean Water Act. Certain wood-derived toxic compounds which are not on the EPA's list of 129 priority pollutants are also present in some wood products industry effluents. Selected additional toxic compounds are listed as numbers 130 through 142 on the priority pollutant list in Table 11.

Annual average effluent limitations for pulp, paper, and paperboard industry subcategories are shown in Table 12. Also shown are the average and range of discharge characteristics for 12 months of wastewater data. The data was developed through effluent guidelines development efforts.

The only toxic pollutant addressed by BPT effluent guidelines is zinc. These limits are shown in Table 13.

BATEA effluent guideline development in the pulp and paper industry will establish effluent limits for other relevant priority pollutants.

Established BPCTCA, standards for other wood products subcategories are summarized in Table 14.

Nonpoint Source Control Regulations

Section 208 of the Clean Water Act is designed to produce areawide waste treatment management planning to assure adequate control of sources of water pollution in each state. The activities not covered by the point source control program are addressed by the nonpoint source planning aspects of Section 208.

TABLE 11. PRIORITY POLLUTANTS

1. *acenaphthene
2. *acrolein
3. *acrylonitrile
4. *benzene
5. *benzidine
6. *carbon tetrachloride
   (tetrachloromethane)

*CHLORINATED BENEZENES (other than dichlorobenzenes)
7. chlorobenezene
8. 1,2,4-trichlorobenzene
9. hexachlorobenzene

*CHLORINATED ETHANES
10. 1,2-dichloroethane
11. 1,1,1-trichloroethane
12. hexacloroethane
13. 1,1-dichloroethane
14. 1,1,2-trichloroethane
15. 1,1,2,2-tetrachloroethane
16. chloroethane

*CHLOROALKYL ETHERS
17. bis(chloromethyl) ether
18. bis(2-chloroethly) ether
19. 2-chloroethyl vinyl ether (mixed)

(continued)

*CHLORINATED NAPHTHALENE
20. 2-chloronaphthalene

*CHLORINATED PHENOLS (Other than those listed elsewhere; includes chlorinated cresols)
21. 2,4,6-trichlorophenol
22. parachlorometa cresol
23. *chloroform (trichloromethane)
24. *2-chlorophenol

*DICHLOROBENZENES
25. 1,2-dichlorobenzene
26. 1,3-dichlorobenzene
27. 1,4-dichlorobenzene

*DICHLOROBENZIDINE
28. 3,3'-dichlorobenzidine

*DICHLOROETHYLENES
29. 1,1-dichloroethylene
30. 1,2-trans-dichloroethylene
31. *2,4-dichlorophenol

*DICHLOROPROPANE AND DICHLOROPROPENE
32. 1,2-dichloropropane
33. 1,3-dichloropropylene
    (1,3-dichloropropene)
34. *2,4-dimenthylphenol

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*Specific compounds and chemical classes as listed in the Consent Decree.

TABLE 11 (continued)

*DINITROTOLUENE
35. 2,4-dinitrotoluene
36. 2,6-dinitrotoluene
37. *1,2,-diphenylhydrazine
38. *ethylbenzene
39. *fluoranthene

*HALOETHERS (Other than those elsewhere)
40. 4-chlorophenyl phenyl ether
41. 4-bromophenyl phenyl ether
42. bis(2-chloroisopropyl) ether
43. bis(2-chloroethoxy) methane

*HALOMETHANES (Other than those listed elsewhere)
44. methylene chloride (dichloromethane)
45. methyl chloride (chloromethane)
46. methyl bromide (bromomethane)
47. bromoform (tribromomethane)
48. dichlorobromomethane
49. trichlorofluoromethane
50. dichloroodifluoromethane
51. chlorodibromomethane
52. *hexachlorobutadiene
53. *hexachlorocyclopentadiene
54. *isophorone
55. *naphthalene
56. *nitrobenzene

*NITROPHENOLS
57. 2-nitrophenol
58. 4-nitrophenol
59. *2,4-dinitrophenol
60. 4,6-dinitro-o-cresol

*NITROSAMINES
61. N-nitrosodimethylamine
62. N-nitrosodiphenylamine
63. N-nitrosodi-n-propylamine
64. *pentachlorophenol
65. *phenol

*PHTHALATE ESTERS
66. bis(2-ethylhexyl) phthalate
67. butyl benzyl phthalate
68. di-n-butyl phthalate
69. di-n-octyl phthalate
70. diethyl phthalate
71. dimethyl phthalate

*POLYNUCLEAR AROMATIC HYDROCARBONS
72. benzo(a)anthracene (1,2-benzanthracene)
73. benzo(a)pyrene (3,4-benzopyrene)
74. 3,4-benzofluoranthene
75. benzo(k)fluoranthene (11,12-benzofluoranthe)

(continued)

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*Specific compounds and chemical classes as listed in the Consent Decree.

TABLE 11 (continued)

*POLYNUCLEAR AROMATIC HYDROCARBONS
(continued)
76. chrysene
77. acenaphthylene
78. anthracene
79. benzo(ghi)perylene (1,12-benzoperylene)
80. fluroene
81. phenathrene
82. dibenzo (a,h)anthracene (1,2,5,6-dibenzanthracene)
83. pyrene
84. pyrene
85. *tetrachloroethylene
86. *toluene
87. *trichloroethylene
88. *vinyl chloride (chlorethylene)

PESTICIDES AND METABOLITES
89. *aldrin
90. *dieldrin
91. *chlordane (technical mixture & metabolites)

*DDT AND METABOLITES
92. 4,4'-DDT
93. 4,4'-DDE (p,p'-DDX)
94. 4,4'-DDD (p,p'-TDE)

*ENDOSULFAN AND METABOLITES
95. a-endosulfan-Alpha
96. b-endosulfan-Beta
97. endosulfan sulfate

*ENDRIN AND METABOLIES
98. endrin
99. endrin aldehyde

*HEPTACHLOR AND METABOLITES
100. heptachlor
101. heptachlor epoxide

*HEXACHLOROCYCLOHEXANE (all isomers)
102. a-BHC-Alpha
103. b-BHC-Beta
104. r-BHC (lindane)-Gamma
105. g-BHC-Delta

*POLYCHLORINATED BIPHENYLS (PCB'S)
106. PCB-1242 (Arochlor 1242)
107. PCB-1254 (Arochlor 1254)
108. PCB-1221 (Arochlor 1232)
109. PCB-1232 (Arochlor 1232)
110. PCB-1248 (Arochlor 1248)
111. PCB-1260 (Arochlor 1260)
112. PCB-1016 (Arochlor 1016)

(continued)

*Specific compounds and chemical classes as listed in the Consent Decree.

TABLE 11 (continued)

113. *Toxaphene
114. *Antimony (Total)
115. *Arsenic (Total)
116. *Asbestos (Fibrous)
117. *Beryllium (Total)
118. *Cadmium (Total)
119. *Chromium (Total)
120. *Copper (Total)
121. *Cyanide (Total)
122. *Lead (Total)
123. *Mercury (Total)
124. *Nickel (Total)
125. *Selenium (Total)
126. *Silver (Total)
127. *Thallium (Total)
128. *Zinc (Total)
129. 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD)

ADDITIONAL COMPOUNDS

130. Abietic Acid
131. Deyhydroabietic Acid
132. Isopimaric Acid
133. Pimaric Acid
134. Oleic Acid
135. Linolenic Acid
136. Linolenic Acid
137. 9,10-Epoxystearic Acid
138. 9,10-Dichlorostearic Acid
139. Monochlorodehydroabietic Acid
140. Dichlorodehydroabietic Acid
141. 3,4,5-Trichloroguaiacol
142. Tetrachloroguaiacol

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*Specific compounds and chemical classes as listed in the Consent Decree.

TABLE 12. COMPARISON OF BPT ANNUAL AVERAGE TO WASTEWATER CHARACTERISTICS FOR THE PULP, PAPER AND PAPERBOARD INDUSTRY

Subcategory	BPT annual average (lb/t)		Final effluent			
			BOD5		TSS	
	BOD5	TSS	Avg.	Range	Avg.	Range
Dissolving kraft	13.8	22.1	19.4	8.1-37.6	30.2	12.4-55.5
Market bleached kraft	9.0	18.0	8.2	4.2-12.2	13.6	4.6-33.3
BCT bleached kraft	8.0	14.2	7.7	3.3-11.1	9.4	3.7-21.3
Alkaline fine	6.2	13.1	13.3	1.5-98.9	20.5	4.1-67.5
Unbleached kraft						
(linerboard)	3.7	7.2	3.7	1.4-7.7	5.9	0.8-13.6
(bag)	3.7	7.2	4.8	2.7-7.7	9.5	4.8-19.3
Semi-chemical	6.4	8.7	6.1	3.2-10.8	8.5	2.7-16.8
Unbleached kraft and semi-chemical	5.9	7.1	5.9	3.5-10.1	18.2	5.8-10.3
Dissolving sulfite pulp	24.2-30.4	41.8	62.2	27.8-102.8	66.0	42.2-113.4
Papergrade sulfite	15.6-22.3	26.0-31.8	23.8	5.7-54.5	24.4	5.0-51.4
Groundwood thermo-mechanical pulp	6.2	9.2	6.4	2.5-10.3	9.1	4.1-14.1
Groundwood CMN papers	4.4	7.5	4.5	1.9-7.1	6.4	5.3-7.5
Groundwood fine papers	4.0	6.9	2.3	0.4-5.9	4.4	0.5-6.9
Deink (fine)	10.6	14.2	5.9	3.7-9.5	8.3	7.3-9.9
(tissue)	10.6	14.2	8.1	2.1-17.1	9.4	2.8-16.2
Tissue from wastepaper	8.0	10.1	7.6	2.2-21.6	14.1	1.6-58.3
Paperboard from wastepaper	1.7	2.3	2.7	0.1-12.9	1.7	0.1-4.1
Wastepaper molded products	--	--	4.1	3.7-4.4	5.5	3.1-7.9
Builder's paper and roofing felt	3.2	3.2	1.7	0.1-3.2	1.9	0.3-3.5
Nonintegrated fine papers	4.8	6.5	12.3	2.1-59.5	17.2	1.4-96.6
Nonintegrated tissue papers	7.0	5.7	3.6	0.5-6.4	2.9	0.9-5.7
Nonintegrated lightweight	--	--	6.8	1.4-17.4	4.6	1.6-8.4
Nonintegrated electrical grade	--	--	--	--	--	--
Nonintegrated filter & nonwoven	--	--	4.4	0.3-8.7	3.4	0.4-4.8
Nonintegrated paperboard	--	--	4.1	0.4-11.2	1.8	0.2-3.5

*BPT limits are shown only for those subcategories where they exist.

Source: Edward C. Jordan Co., Inc. BATEA Review Program.

TABLE 13. BPCTCA ZINC GUIDELINES
FOR THE PULP, PAPER AND PAPERBOARD INDUSTRY

Subcategory*	Maximum 30-day average kg/kkg(lb/ton)	Maximum day kg/kkg(lb/ton)
GW:Chemical-mechanical	0.115 (0.23)	0.23 (0.46)
GW:Thermo-mechanical	0.065 (0.13)	0.13 (0.26)
GW:CMN Papers	0.120 (0.24)	0.24 (0.48)
GW:Fine Papers	0.115 (0.23)	0.23 (0.46)

Source: U.S. Environmental Protection Agency(71)

*Only subcategories for which zinc limitations exist are shown.

TABLE 14. BPT EFFLUENT GUIDELINES FOR OTHER WOOD PRODUCTS SUBCATEGORIES

Industry subcategory	Effluent limits						
	BOD5		TSS			Other (specify	
	Maximum day	30-day average	Maximum day	30-day average	pH	Maximum day	30-day average
	kg/cu m (lbs/cu ft)	kg/cu m (lbs/cu ft)	kg/cu m (lbs/cu ft)	kg/cu m (lbs/cu ft)			
. Barking*#	1.5(0.09)	0.5(0.03)	6.9(0.431)	2.3(0.144)	6.0-9.0		
. Veneer softwood#†	0.72(0.045)	0.24(0.015)			6.0-9.0		
. Veneer hardwood#†	1.62(0.10)	0.54(0.034)			6.0-9.0		
. Plywood#†	No discharge						
. Hardboard-dry process#†	No discharge						
	kg/kkg(lb/t)	kg/kkg(lb/t)	kg/kkg(lb/t)	kg/kkg(lb/t)			
. Hardboard-wet process#†	7.8 (15.6)	2.6 (5.2)	16.5 (33.0)	5.5 (11.0)	6.0-9.0		
. Wood preserving#†	No discharge						

(Continued)

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*Hydraulic barkers shall be defined as wood processing equipment that has the function of removing bark from wood by the use of water under a pressure of 68 atm (1000 psi) or greater.

#The term cu m of production shall mean the cu m of veneer or plywood produced by the manufacturing facility as the end product as determined by a daily production figure or a 30-day production period.

†Specifically excluded from the term "process wastewater" for this subpart are cooling water, material storage yard runoff (with raw material or processed wood storage), fire control water (when kept separate from processing materials), and boiler blowdown.

TABLE 14 (Continued)

Industry subcategory	Effluent limits						
	BOD5		TSS			Other (specify	
	Maximum day	30-day average	Maximum day	30-day average	pH	Maximum day	30-day average
	kg/cu m (lbs/cu ft)	kg/cu m (lbs/cu ft)	kg/cu m (lbs/cu ft)	kg/cu m (lbs/cu ft)			
. Wood preserving-steam#†					6.0-9.0	COD kg/kkg(lb/t) 1100 (68.5) Phenols kg/kkg(lb/t) 2.18 (0.14) Oil & grease kg/kkg(lb/t) 24.0 (1.5)	 kg/kkg/(lb/t) 550 (34.5) kg/kkg/(lb/t) 0.65 (0.04) kg/kkg/(lb/t) 12.0 (0.75)
. Wood preserving boultonizing#†	No discharge						
. Wet storage					6.0-9.0	Debris§ None	
. Log washing			[mg/l] Instantaneous 50		6.0-9.0		
. Sawmills and planning mills†	No discharge						

(Continued)

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†Specifically excluded from the term "process wastewater" for this subpart are cooling water, material storage yard runoff (with raw material or processed wood storage), fire control water (when kept separate from processing materials), and boiler blowdown.

§"Debris" means a woody material such as bark, twigs, branches, heartwood, or sapwood that will not pass through a 2.54-cm (1.0 in.) diameter round opening that might be present in the discharge from a wet storage facility.

TABLE 14 (Continued)

Industry subcategory	Effluent limits BOD5 Maximum day	BOD5 30-day average	TSS Maximum day	TSS 30-day average	pH	Other (specify Maximum day	Other (specify 30-day average
	kg/cu m (lbs/cu ft)	kg/cu m (lbs/cu ft)	kg/cu m (lbs/cu ft)	kg/cu m (lbs/cu ft)			
. Finishing†Δ	No discharge						
. Particle-board manufacturing†∇	No discharge						
. Wood furniture and fixture production without water wash spray booths or laundry facilities	No discharge						
						Settleable solids(ml/l) instantaneous	
. Wood furniture and fixture production with water wash spray booths or laundry facilities					6.0-9.0	0.2	

(Continued)

†Specifically excluded from the term "process wastewater" for this subpart are cooling water, material storage yard runoff (with raw material or processed wood storage), fire control water (when kept separate from processing materials), and boiler blowdown.

ΔThe term "byproduct utilization" shall be the manufacture of products from bark and wood waste materials but does not include the manufacture of insulation board, particleboard, or hardboard.

∇The term "particleboard" means board products that are composed of distinct particles of wood or other lignocellulosic materials not reduced to fibers which are bonded together with an organic or inorganic binder.

TABLE 14 (Continued)

	Effluent limits						
	BOD5		TSS			Other (specify	
Industry subcategory	Maximum day	30-day average	Maximum day	30-day average	pH	Maximum day	30-day average
	kg/cu m (lbs/cu ft)	kg/cu m (lbs/cu ft)	kg/cu m (lbs/cu ft)	kg/cu m (lbs/cu ft)			
Gum and wood chemicals manufacturing point source category							
. Char and charcoal briquettes	No discharge						
. Gum rosin and turpentine	1.42	0.755	0.077	0.026	6.0-9.0		
. Wood rosin, turpentine, and pine oil	2.08	1.10	1.38	0.475	6.0-9.0		
. Tall oil rosin, pitch, and datty acids	0.995	0.529	0.705	0.243	6.0-9.0		
. essential oils	22.7	12.0	9.01	3.11	6.0-9.0		
. Rosin-based derivatives	1.41	0.748	0.045	0.015	6.0-9.0		

Source: U.S. Environmental Protection Agency (13,14)

One of the ways to differentiate point and nonpoint sources of pollution is to look at the treatment or control measures available for a given source. Most nonpoint sources are best handled using land management techniques rather than effluent treatment, i.e., it's more practical and economical to control nonpoint pollution at its source than to collect the runoff and transport it to a wastewater treatment plant.

Nearly all nonpoint source pollutants are storm-generated, and most are rural in nature. EPA has arrived at eight categories of nonpoint pollution: agriculture; silviculture; construction; mining; hydrologic modifications; practices primarily affecting groundwater; residual waste disposal; and urban runoff. While construction and urban runoff are major factors in urban areas, the remaining categories are prevalent in rural areas.

EPA realizes that the magnitude of the nonpoint source problems is immense - possibly greater than the total problem caused by point sources. It is estimated that 15 percent of the nation's waters are failing to meet water quality standards due to nonpoint sources and another 35 percent are equally degraded by a combination of point and nonpoint sources. The effects of these nonpoint sources will become more evident as we further reduce pollution due to point sources through applied control technology.

EPA's approach to nonpoint source pollution control has been to establish, by regulation, the concept of best management practices (BMP's). These are defined as:

> "a practice, or combination of practices, that is determined after problem assessment, examination of alternative practices, and appropriate public participation to be the most effective, practicable (including technological, economic, and institutional considerations) means of preventing or reducing the amount of pollution generated by nonpoint sources to a level compatible with water quality goals."

Thus, BMP's are broadly defined in terms of objectives, rather than specific control activities. In adopting this approach, EPA has recognized four important facts:

1. that essentially there is no one right way to prevent, manage, or control nonpoint source pollution problems;

2. that due to such uncontrollable factors as climate and geography, the same problem-solving techniques cannot be applied everywhere and produce the same results;

3. that the physical environment together with legal, political, and institutional conditions differs from area to area, to such an extent as to make rigid federal requirements for control inappropriate and unworkable; and

4. that successful management of nonpoint sources and of the 208 program must involve the continual integration of technical, administrative, and regulatory functions and skills.

For the most part, effective land management techniques are known and many are in daily use throughout the country. These will form the options from which BMP's will be chosen. As an example, the Soil Conservation Service, Forest Service, Soil and Water Conservation Districts, Extension Services, and a host of other federal, state, and local agencies have worked for many years to develop land management techniques to keep the soil on the land. When these techniques are evaluated from the slightly different perspective of keeping the soil out of the water, they become BMP's.

POLLUTANT CHARACTERIZATION AND IMPACT

Specific pollutants found within the wood products industries include conventional, toxic, and nonconventional pollutants, many of which are contributed by both point and nonpoint sources. Pollutants of concern are introduced below.

Conventional and Nonconventional Pollutants from the Pulp, Paper, and Paperboard Industry

Conventional pollutants include biochemical BOD_5, TSS, pH, color, chemical oxygen demand (COD), coliform bacteria, phosphorus, and oil and grease. Nonconventional pollutants include color and a number of additional potentially toxic organics not included as priority pollutants. The potentially toxic nonconventional pollutants will be discussed later in this section, along with the priority pollutants.

This document will concern itself primarily with BOD_5, TSS, pH and color. These four pollutants can be interrelated. For example, biological solids contribute to both BOD_5 and TSS; dissolved organics can contribute to both BOD_5 and color; and the pH can affect the solubility and color of these materials.

Possible adverse environmental impacts of these pollutants include:

1. Organisms discharged from biological treatment systems can survive and increase in the stream environment. This can affect higher organism populations.

2. Solids not removed by treatment tend not to settle out of suspension after discharge due to their small diameters and turbulence in streams. This can hinder light penetration and affect algal populations.

3. Dissolved organic materials discharged can stimulate native stream bacteria, which can affect higher organisms. The stimulative effect, however, is limited by the available nutrients in the stream.

4. Colored effluents can have adverse aesthetic effects on receiving waters, and can also hinder light penetration.

5. Excessive amounts of BOD5 or extreme levels of pH in effluents can be lethal to aquatic organisms by depleting dissolved oxygen or altering the pH of the receiving water. Loss of oxygen can also cause the release of reduced malodorous compounds.

6. Compounds contributing to color and BOD5 may cause effluent foaming which can have adverse aesthetic effects.

The Academy of Natural Sciences of Philadelphia has performed a study on the environmental effects of biologically treated effluent solids from a Procter and Gamble pulp and paper mill in Mehoopany, Pennsylvania.(8) They conclude that the nonsettleable organic matter which is discharged has very little effect on the receiving stream in terms of light penetration, settleability, bacterial growth, algal growth and stream protozoan populations. They also state that the minor effects which were observed may slightly increase the productivity of the receiving waters and their ability to support life.

Lee, Mueller and Walden(9) point out that nonsettleable solids have a substantially different impact on receiving waters than settleable solids, although current regulations address only total suspended solids. Settleable solids are readily removed from solution. Because nonsettleable solids are not readily removed, their effects on water quality can be long-lasting.

Effluents from ten pulp mills and one newsprint mill were evaluated to determine the magnitude of these effects. Nonsettleable solids were found to amount to 5 to 21 pounds (lb) per air dry ton (ADT) of product. This would cause 2 milligrams/liter (mg/l) suspended solids in receiving waters assuming a dilution of 1/40. At this dilution, the receiving water turbidity is increased by about 1 Nephelometric Turbidity Unit (NTU).

The half-life for nonsettleable biological effluent solids was approximately one month. No biodegradation was observed over a period of one month for clarified, limed effluent nonsettleable solids. In the stream, these solids scatter light in the upper layers of the receiving water, and reduce light penetration in the zone where photosynthetic activity occurs. The effect of solids on light penetration was believed to be less than that of the color in the effluents (10 to 25 alpha units). This is because the color absorbs the light, while the suspended particles reflect it.

Biological nonsettleable solids release nutrients to the receiving waters. The most important of these are nitrogen and phosphorus, although trace elements are also believed to be released. Limed, clarified effluent solids are poor in nutrients, with minimal fertilization effect.

The overall impact of the biologically treated effluents at 1/40 dilution (1 to 2 mg/l solids) was to stimulate algal productivity through nutrient release; no harmful (inhibitive) effects on aquatic life activity were observed at this dilution. The effluent however, could have an adverse affect on some oligotrophic waters, and/or if the dilution was less than that assumed in this study.

Borton (182) concluded that the addition of one mg/l BOD_5 of biologically treated bleached kraft mill effluent to artificial streams had no effect on the spawning of either bluegill sunfish or bass. The effluent addition had no observable effects on the benthos of the stream.

Toxic Pollutants from the Pulp, Paper, and Paperboard Industry

Introduction--

Only recently have any significant steps been taken to identify and quantify concentrations of specific toxic compounds discharged by the U.S. wood products industry. Reported data is generally a result of isolated studies, many of which relate to specific mill effluents and receiving waters.

Toxic materials in pulp, paper, and paperboard mill effluents derive primarily from the wood furnish. These are resin and fatty acids and, where pulp bleaching is practiced, their chlorinated analogues. Resin acids are present in many softwoods but are often absent in hardwoods. Other toxic materials may result from chemical additives, such as dyes, containing heavy metals.

A general summary of toxic water pollutants from the wood product industries is presented, followed by more specific data concerning the concentration of toxic compounds by industry subcategory.

Identification and Impact of Major Toxic Pollutants in Wood Products Industry Effluents--

Selected toxic materials found in pulp, paper, and paperboard other wood product industries effluents include those shown in Table 15. As noted in the table, many wood-derived substances are not currently listed on the EPA's priority pollutant list. The compounds listed in Table 15 can have lethal or sublethal effects on aquatic organisms in receiving waters. When lethal effects are observed, the effluent is considered to be acutely toxic. The combined effects of these compounds is limited for most effluent discharges. Recent studies (15) indicate that pulp bleaching effluents may have mutagenic effects on aquatic life. An overriding concern is the high volume of effluent discharged by the industry. These and other aspects of toxicity are discussed in more detail below.

Receiving Water Quality Criteria for Toxic Pollutants--

Toxic pollutants which have been identified in wood products industry effluents, and for which receiving water quality criteria have been proposed are summarized in Table 16. As seen, receiving water quality criteria have not been established for most of the toxic pollutants found in wood products effluents.

TABLE 15. SELECTED POTENTIALLY TOXIC MATERIALS FOUND IN PULP, PAPER AND OTHER WOOD PRODUCTS

Resin Acids
- Abietic Acid*, Dehydroabietic Acid*, Isopimaric Acid*, Pimaric Acid*, Levopimaric*, Palustric*, Sandaracopimaric*, Neoabietic*

C-18 Unsaturated Fatty Acids
- Oleic*, Linoleic Acid*, Linolenic Acid*, Palmitoleic*

Other Acidics
- Epoxystearic Acid*, Dichlorostearic Acid*, Acetic Acid

Chlorinated Resin Acids
- Monochlorodehydroabietic Acid*, Dichlorodehydroabietic Acid*

Phenolics
Chlorinated Phenolics
- 3,4,5 Trichloroguaiacol*, Tetrachloroguaiacol*, Paraclorometa Cresol*, Pentachlorophenol

Halomethane
- Chloroform

Heavy Metals
- Zinc, Lead

Polychlorinated Biphenyls (PCB's)

Lignin Degradation Products*
- Eugenol, Isoeugenol, 3-3dimethoxy, 4-4dihydroxystilbene

Juvabiones*
- Juvabione, Juvabiol, 1'-Dehydrojuvabione, 1'-Dehydrojuvabiol, Dehydrojuvabiol

Other Neutrals*
- Abienol, 12E-abienol, 13-epimanool

Dipertene Alcohols*
- Pimarol, Isopimarol, Dehydroabietal, Abietal, Furfural*

Volatiles*
- Hydrogen Sulfide, Methyl Mercaptan, Sodium Sulfide

*Not included in priority pollutant list.
Source: Batelle Columbus Laboratories, Multi-Media Pollution Assessment In Pulp, Paper, and Other Wood Products Industry, 1976.

TABLE 16. PROPOSED RECEIVING WATER QUALITY CRITERIA

	AQUATIC LIFE CRITERIA				HUMAN HEALTH EFFECTS AMBIENT CONCENTRATION (mg/l)			
	FRESH WATER		SALT WATER					
Compound name	avg.* (ug/l)	max. (ug/l)	avg. (ug/l)	max. (ug/l)	Maximum Protection	interim target 10^5	10^6	10^7#
Benzene(16)	3100	7000	920	2100	0	15	1.5	0.15
Chloroform(16)	500	1200	620	1400	0	2.1	0.21	0.021
Lead(16)	(1.51A-3.37)	(1.51A-1.39)	N.D.†	N.D.	1.0	N.A.§	N.A.	N.A.
	where A = ln hardness							
Pentachlorophenol(16)	6.2	14.0	3.7	8.5	140	N.A.	N.A.	N.A.
Vinyl Chloride(16)	N.D.	N.D.	N.D.	N.D.	0	517	51.7	5.17
Mercury(17)	N.D.	0.25	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
PCB's(17)	N.D.	$2x10^{-3}$	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Zinc(17)	N.D.	Δ	N.D.	N.D.	5000	N.D.	N.D.	N.D.
Phenolic compounds(17)	N.D.	100	N.D.	N.D.	1.0	N.D.	N.D.	N.D.

*Avg. = 24-hour average.

#Additional cancer risk of 1/100,000, 1/1,000,000 and 1/10,000,000, respectively.

†N.D.= No data

§N.A.= Not applicable.

ΔMaximum value is 0.005 times the 96-hr LC-50.

Measuring Acute Toxicity to Fish--

Most studies of the toxicity of pulp, paper, and paperboard wastes are based on bioassay procedures which indicate effluent concentrations at which fish survival is threatened. Toxic compounds which are diluted in large quantities of wastewater will have less toxicity than those compounds which are present in higher concentrations. The concentration which results in a 50 percent fish survival rate after 96 hours of exposure is termed the 96-hr LC-50. This concentration can be expressed either as a percentage of dilution or in terms of mg/l.

Toxicity is substantially affected by pH, with higher toxicities occurring in the lower pH range. For this reason, 96-hr LC-50 values are usually reported for pH 7.5. It is generally agreed among researchers that the observed sublethal toxicity threshold is from 0.05 to 0.1 times the 96-hr LC-50 concentration.

The effect of combining certain amounts of two or more toxic compounds may be approximated with the toxic unit (TU) concept developed by Sprague.(18) By this technique a common basis of toxic units is established as shown:

$$\text{TU} = \frac{\text{actual concentration of compound}}{\text{96-hr LC-50 of compound}}$$

By making the assumption that toxic units are additive, a toxic measure of the waste may be determined from chemical assay data. Synergistic effects, however, which may occur among various pollutants in solution may introduce error in the calculated TU value.

Bioassay data may be approximately expressed in toxic units by the relationship below:

96-hr LC-50	1	2	3	4	5	10	20	30	40	50	100
TU	100	50	33	24	20	10	5	3.3	2.5	2.0	1.0

The relation between 96-hr LC-50 and TU may vary between compounds. Given these limitations, though, the toxic unit concept is a useful tool for relating chemical assay to bioassay data. More research to establish the correlation between chemical assay and bioassay data is recommended. For purposes of this discussion a waste exhibiting a TU of less than 1 is considered nontoxic.

Raw Effluent Toxicity--

Many raw pulp, paper, and paperboard mill effluents exhibit a limited degree of toxicity. The major concern over this toxicity originates from large volumes of low concentration effluents. Typical water use is indicated in Table 17.

TABLE 17. WATER USE IN PULP AND PAPER PRODUCTION

Unit Process	Water usage (gal/ton)
Hydraulic debarking	500-10,000
Groundwood	6,500-10,000
NSSC pulping	3,000-20,000
Kraft pulping	20,000-30,000
Sulfite pulping	20,000-30,000
Bleaching	20,000-40,000

A summary of the range of LC-50 concentrations (expressed as percent dilution of raw waste) for various wood pulping and bleaching processes is shown in Table 18. As shown the 96-hr LC-50 of the various effluents can vary from 4 to 100 percent by volume, with mechanical pulping effluents being the most toxic. It should be noted, however, that the compounds contributing to mechanical pulping effluent toxicity are more amenable to biodegradation than chlorinated compounds in bleachery wastes.

TABLE 18. MEDIAN LETHAL CONCENTRATIONS FOR VARIOUS RAW PULPING EFFLUENTS

Pulping process	96-Hr LC-50 (%v/v)	Reference
Unbleached kraft	10-100	(18,19,10,21)
Bleached kraft	10-100	(22)
Mechanical pulping	4-10	(23)
Sulfite	10-100	(24)
Deink	3-20	(25)
Paperboard	20-40	(25)
Woodroom	1-50	(26)

A brief account of raw effluent toxicity for major pulping processes is presented in the following paragraphs. Several researchers have reported bioassay data concerning raw kraft mill waste. A wide range of results are reported, with 96-hr LC-50 concentrations usually falling between 10 and 100 percent by volume.(18,19,20,21) This confirms a variable but relatively low toxicity of raw kraft mill wastes. Although some researchers (22,27,28) have reported LC-50 values between 1 percent and 10 percent by volume, Howard and Walden (19) attribute much of this reported higher toxicity data to an imbalance in pH. In the same study they show that test fish could build up a resistance to kraft effluent toxicity by being exposed to successively greater concentrations. This phenomena is worthy of further study for verification and/or quantification.

Studies have also been performed on the toxicity of raw kraft wastes to invertebrates.(18,29) No invertebrates tested were more sensitive than fish, while some were appreciably more resistant than fish to raw effluent toxicity.

The prime contributors to toxicity in kraft pulping effluents are resin acids and fatty acids, which occur naturally in wood. Leach and Thakore (30) investigated the toxicity of unbleached kraft whitewater from 50 percent Douglas fir and 50 percent western hemlock (both softwood). The raw effluent was found to have a mean survival time of 30 minutes to juvenile coho salmon at 100 percent concentration. Resin acids soaps (found at 14.1 mg/l) were demonstrated to account for 82 percent of the toxicity. The specific toxicants found and their respective concentrations and contribution to toxicity are shown in Table 19. These results illustrate the presence of resin and fatty acids in the furnish.

Raw whitewater from three unbleached kraft mills and five combinations of wood species were evaluated for 96-hr LC-50 concentrations and specific resin and fatty acid content by Leach and Thakore.(30) Four of the samples from two mills processing up to 50 percent by volume. A fifth mill processing approximately 18 percent hardwood yielded a 96-hr LC-50 of 20 percent. The acute toxicity was directly related to the total resin acid loading. There was no discernible relation, however, to the resin acid content and the relative mixture of hardwood and softwood. The results are summarized in Table 20.

The Institute of Paper Chemistry (IPC) has reported nonconventional pollutant loads from four unbleached kraft mills.(31) Resin and fatty acid loadings from the three mills processing predominantly pine were consistently greater than for the one using predominantly Douglas fir. As shown in Table 21, the results show a trend of high resin and fatty acid contents from effluents pulping a high percentage of pine. Leach and Thakore (32,33) have reported the toxic constituents in raw caustic bleachery wastes and their 96-hr LC-50's to be: 3,4,5 trichloroguaiacol, 0.75 mg/l; 3,4,5,6 tetrachloroguaiacol, 0.32 mg/l; monochlorodehydroabietic acid, 0.6 mg/l; dichlorodehydroabietic acid 0.6 mg/l; 9,10 epoxystearic acid, 1.5 mg/l.

Leach and Thakore (32,33) reported that toxic parameter concentrations of trichloroguaiacol, 0.2 to 1.2 mg/l; tetrachloroguaiacol, 0.2 to 1.1 mg/l; monochlorodehydroabietic acid, not detected to 4.3 mg/l; dichlorodehydroabietic acid, not detected to 2.5 mg/l; epoxystearic acid, 1.5 to 17 mg/l. The concentrations of these parameters accounted for 2.3 to 24.0 toxic units, or 50 to 100 percent of the total raw bleachery waste toxicity. The mean and range mass loading for each parameter are shown in Table 22.

TABLE 19. UNBLEACHED KRAFT PULP MILL EFFLUENT TOXICITY

Source	Wood species	Raw effluent concentration (mg/l)		Toxicity	Comments
Unbleached	50% Douglas fir 50% Western hemlock	Total resin acid soaps	14.1	82%	Resin acids in the form of sodium salts were much more toxic than free resin acids. All toxicants originated from unrecovered dilute black liquor.
		Sodium isopimarate	5.62	55%	
		Sodium abietate	5.73	22%	
		Sodium dehydroabietate	2.2	5%	
		Sodium sandaraco pimarate	0.6	neg.	
		Total fatty acids	8.2	18%	
		Linolenic fatty acid	3.57	NR	
		Oleic fatty acid	1.53	NR	
		Linoleic fatty acid	1.08	NR	
		Palmitoleic fatty acid	1.02	NR	

Source: Leach and Thakore(30)
NR - Not Reported.

TABLE 20. ANALYSIS OF UNBLEACHED WHITEWATER SAMPLES

Mill location sample no.	Ontario A1	 A2	 A3	British Columbia B1	 B2	Interior Ontario C1
Wood species	25% Dense hardwood* 75% Jackpine	50% Dense hardwood*, 50% Jackpine	25% Poplar 75% Jackpine	50% White spruce 30% Lodgepole pine 20% Douglas fir		Elm 28%, soft maple 18%, Hard maple 12%, Poplar 12%, Pine 8% Miscellaneous 22%
Unbleached pulp prod. (tons/day)	723	697	700	685	761	--
Effluent flow (gpm)	1,050	720	1,450	1,330	880	430
Effluent Analyses:						
pH	11.2	10.0	-	10.7	10.4	9.5
Toxicity (96-hr LC-50)	3%	5%	-	3%	2%	20%
TOC (mg/l)	595	515	-	1,216	683	--
BOD_5 (mg/l)	540	575	-	1,300	970	--
Resin Acids (mg/l):						
Pimaric & sandaracopimaric	2.6	2.0	2.0	8.7	5.3	0.7
Isopimaric	17.2	6.2	5.7	12.7	10.4	1.8
Abietic	12.9	15.9	7.6	13.2	9.3	2.8
Dehydroabietic	22.1	9.6	7.4	13.9	7.6	2.3
Total resin acids	54.8	33.7	22.7	48.5	32.6	7.6

(Continued)

*Dense hardwood: maple, birch, elm, ash

TABLE 20 (Continued)

Mill location sample no.	Ontario A1	 A2	 A3	British Columbia B1	 B2	Interior Ontario C1
Resin acid loading(lb/day)	800	340	440	870	390	--
(lb/ton pulp)	1.1	0.5	0.6	1.3	0.5	--
Fatty acids (mg/l):						
Oleic	3.2	2.6	1.8	4.8	3.4	0.5
Linoleic	8.6	6.6	4.0	10.9	10.4	0.8
Linolenic	1.3	4.1	0.9	4.5	3.2	0.7
Total C_{18}-unsaturated fatty acids	13.1	13.3	6.7	20.2	17.0	2.0

*Dense hardwood: maple, birch, elm, ash.

Source: Leach and Thakore (30)

TABLE 21. UNBLEACHED KRAFT EFFLUENT NONCONVENTIONAL POLLUTANT LOADINGS

	Furnish			
	85% Pine 15% H.W.	90% Pine 10% Misc.	95% Pine 5% H.W.	85% Douglas Fir 15% Pine
	Priority pollutant loadings (lb/ton)			
Resin acids				
abietic	0.25	0.34	1.0	0.05
dehydroabietic	0.28	0.32	1.1	0.06
isopimaric	0.08	0.12	0.4	0.15
pimaric	0.08	0.09	0.3	0.004
TOTAL	0.69	0.87	2.8	0.264
Unsaturated fatty acids				
oleic	0.3	0.64	0.7	0.06
linoleic	0.16	0.5	0.4	0.04
linolenic	0.003	0.01	0.05	0.004
TOTAL	0.46	1.15	1.15	0.104

Source: Easty, et al (31)

TABLE 22. KRAFT BLEACHERY NONCONVENTIONAL POLLUTANT LOADING

Priority pollutant	Mean loading (lb/ton)	Range (lb/ton)
tetrachloroguaiacol	0.01	0.004-0.03
trichloroguaiacol	0.02	0.004-0.06
monochlorodehydroabietic acid	0.02	0.004-0.06
dichlorodehydroabietic acid	0.02	0.007-0.06
dehydroabietic acid	0.01	0.002-0.04
epoxystearic acid	0.15	0.007-0.47
dichlorostearic acid	0.06	0.007-0.15
chloroform	*	*

*No data

Source: Leach and Thakore (32,33)

Although the data suggests that there may be some correlation between pollutant loading and wood furnish, no specific relation can be supported at this time.

Experiments by Leach and Thakore at B.C. Research have shown chlorination stage effluents rendered nontoxic by adjustment to alkaline pH.(34) The toxic constituents of chlorination stage effluent have not yet been determined.

Wilson and Chappel (35) studied raw sulfite waste with the following LC-50 results: soda base, 11.6-60.0 percent; ammonia-base 8.7-25.0 percent. In a follow-up to this study, the raw waste from a soda base mill processing 40 percent poplar, 40 percent maple, and 20 percent elm with high water reuse (3,500 gal/ton) had 96-hr LC-50's of from 10 to 28 percent. The hardness of the raw waste was found to be inversely related to toxicity. Raw sulfite waste toxicity data is less abundant than that for raw whole mill kraft wastes.

Toxic constituents in sulfite effluents have been examined by Wilson and Chappel.(35) Phenolic compounds accounted for 28 percent of the total toxicity in a high yield soda base plant. These compounds were eugenol, trans-iso-eugenol, and 3,3' dimethoxy, 4,4' dihydroxystilbene. Resin acids contributed only 26 percent of the total toxicity with the remaining 48 percent unknown.

Hruitfiord (36) has reported the effluent composition of a calcium base plant, without attempting to establish the toxicities of these compounds (Tables 23 and 24). Of these compounds only extractives (resin and fatty acids) are currently under study in the pulp, paper, and paperboard industry wastewaters.

Wilson and Chappel (35) have summarized the toxicities of these compounds as determined by Meinick.(37) This data is also presented in Table 23 and 24.

Kvasnick and McLaughlin(38) found no resin acids in effluent from spruce sulfite pulping, while Nelson and Hemingway (39) report that resin acids account for 40 percent of the ether extractable portion of bisulfite waste liquor. From this data it is recommended that additional toxic pollutant analyses be performed, especially for sulfite wastes.

Row and Cook (40) found that resin acid soaps are the major contributor to raw mechanical pulping waste toxicity. Studies of several Canadian groundwood mills (26,41) indicate that toxicity is largely dependent on water recycle and that softwoods produce more toxic effluents than hardwoods.

Leach and Thakore (26) performed a study to identify the toxic constituents in raw groundwood waste from the processing of softwood. Resin acids identified as contributing significantly to toxicity include: abietic, dehydroabietic, and palustric. Minor toxicity contributing resin

TABLE 23. COMPOSITION OF SULFITE WASTE LIQUOR SOLIDS

Component	% of dissolved solids	Reported toxicity to fish
Lignin sulfonates	52-56	N.R.
Extractives	3	See note
Poly- and oligo-saccharides	6	N.R.
Monosaccharides	23	N.R.
Glucuronic acid	1	N.R.
Aldonic acids	4	N.R.
Sugar sulfonates	3	N.R.
Acetic acid	2	LC-50 50 ppm in Rainbow Trout
Methanol	1	LC-50 8100 ppm in Trout
Calcium	5	LC-50 2500 ppm

Source: Wilson and Chappel(145)
N.R. = Not reported

TABLE 24. VOLATILE ORGANIC COMPONENTS IN SULFITE WASTE LIQUOR

Component	Estimated lb/ton	Toxicity to fish
Acetic Acid	80	LC-50 50 ppm, rainbow trout
Methanol	20	LC-50 8100 ppm, trout
Furfural	5	LC-50 = 16 ppm in *Lepomis machrochirus* (48 hr value)
Ethanol	4	LC-50 7,000 ppm in Creek chub *(Semolitus Atromaculatus)*
Methyl glyoxal	4	Not reported
Acetone	1	Threshold of perturbation to trout is 2,000 ppm
Acetaldehyde	1	LC-50 70 ppm in pinperch
Formic acid	1	Threshold of perturbation to rainbow trout is 1,000 ppm
Others	5	-----

Source: Wilson and Chappel(145)

acids were pimaric, sandaracopimaric, isopimaric and neoabietic. Toxic unsaturated fatty acids found were: oleic, linoleic and linolenic. Up to 30 percent of the toxicity was attributed to phenolic compounds, including: pimarol, ispimarol and juvabione.

Woodroom wastes have been confirmed as toxic to fish.(25,42) In a study of woodroom effluent toxicity, B.C. Research found the 96-hr LC-50 of raw hardwood waste to be 50 percent by volume, while that of softwood was 1 percent by volume.(43) The relatively high toxicity in raw softwood woodroom effluent is primarily caused by the high resin acid content of softwood bark.

Eastern softwood debarking effluents were reported to contain resin acids at 37.5 mg/l, in the following concentrations:(44)

Isopimaric	2.5 mg/l
Abietic	17.5 mg/l
Dehydroabietic	4.1 mg/l
Neoabietic	6.1 mg/l
Palustric	7.3 mg/l
TOTAL	37.5 mg/l

In addition, 14.8 mg/l of fatty acids and non-acidic toxicants were found as follows:

C-18 Unsaturated fatty acids	0.5 mg/l
13 Epimanool	1.2 mg/l
Abienol	13.8 mg/l
TOTAL	14.8 mg/l

The resin acid loading corresponded to 0.14 to 0.15 mg/ton of wood debarked.

Debarked effluent from a west coast mill processing western hemlock and Douglas fir yielded a total resin and fatty acid content of only 1.33 mg/l, as follows:(144)

Oleic	0.16 mg/l
Linolenic	0.05 mg/l
Pimaric	0.15 mg/l
Abietic	0.46 mg/l
Isopimaric	0.12 mg/l
Dehydro and neoabietic	0.39 mg/l
Total	1.33 mg/l

Preliminary investigation of a hardwood debarking effluent yielded an LC-50 of 40 percent by volume. No resin and fatty acids were readily identifiable.

These preliminary results indicate that eastern softwood debarking effluent may be significantly more toxic than that for either hardwood or western softwood.

Martins, et al. (45) in a study of deinking and paperboard effluents determined that detergents were a major cause of effluent toxicity. Acute deinking wastewater toxicity in terms of 96-hr LC-50 concentrations by volume for sockeye salmon fingerlings and pink salmon fry were reported as follows: ledger, 3 to 7 percent by volume; newsprint, 5 to 20 percent. In the same study, the toxicity of paperboard effluent and combined paperboard, newsprint and ledger effluents ranged from 23 to 43 percent by volume.

The New York State Department of Conservation has conducted a study concerning PCB's in wastepaper mill effluents.(46) Of the 40 mills in New York State using some wastepaper, 18 were selected as potential direct discharges of PCB's. Monthly final effluent samples were analyzed from October 1976 to September 1978. Sampling types ranged from grab to flow proportioned 24-hour composite samples for the 18 mills. Most mills employed secondary treatment prior to discharge.

The results are summarized as follows:

- 81 percent of all samples showed PCB concentrations of less than 1 ppb.
- The average of all reported median mill PCB concentrations was 0.76 ppb.
- The average of all median mill PCB levels, excluding mills without effluent treatment, was 0.61 ppb.

- The discharge of PCB's for any given mill was variable, with several reported values above 10 ppb. The highest value was 18 ppb, which may have resulted from the purchase of highly contaminated wastepaper.

These results imply that PCB concentrations from wastepaper mills are generally below 1 ppb and that the concentration may be reduced by secondary treatment. Occasional periods of higher concentrations occur, although their cause is unknown.

There is an apparent lack of published literature on specific effluent toxicity originating from additives used in various papers. Heavy metals orginate largely from pigments added in paper coating and glazing operations. The specific toxic contribution of these metals is not known; however, it is believed to be minor compared to wood-derived compounds.

As solutions approach lethal concentrations adverse sublethal affects have been observed for aquatic organisms including alteration of fish flesh color and taste, and impairment of mobility and development. A summary of reported sublethal concentrations of kraft and sulfite effluents for various organisms is indicated in Table 25.

In a recent study Ander (15) has observed chlorination stage effluents from kraft bleaching to cause mutations in two strains of Salmonella bacteria. A weak mutagenic effect was also observed for hypochlorite stage bleaching effluent. The addition of human liver microsomes to the chlorination stage effluent decreased the mutagenic effect. This suggests that the mutagenic compounds would be partly degraded in the liver.

Chloroform has been shown to induce cancer in laboratory animals.(47) These results suggest that further research is warranted to establish the magnitude of these impacts on aquatic and human life.

Relative toxic contributions of certain classes of materials found in various pulping and bleaching effluents, as summarized by Walden (19) are shown in Table 26. All of these compounds are either wood-derived or products of wood-derived substances. Dependency on wood source tends to complicate the characterization of toxic pollutant loadings by subcategory. Pines, for example, have a much higher resin acid content than many other softwoods, while hardwoods often exhibit no detectable resin acids. Reported compositions of various wood species based on a literature review by Swan (48) are shown in Table 27.

Variance in resin and fatty acid content was observed within the major species groups indicated. One study showed substantial variance in resin acid content within the same species for differing tree ages. Specifically, pinus bansiana was evaluated for six resin acids in trees of differing diameters.(23) The relative percentage of individual resin acid content was almost always progressively higher with an increase in diameter. The total identified resin acid contents and respective tree diameters are summarized in Table 28.

TABLE 25. THRESHOLD OF SUBLETHAL CONCENTRATIONS OF KRAFT MILL AND SULFITE MILL EFFLUENTS

Specie	Sublethal Effects	Kraft Mill Effluents*
Spring and coho	Growth, distress	0.12-0.14
Coho	Swimming	0.1 -0.2
Spring	Growth	0.12
	Growth	10% v/v
Coho	Growth	>0.25
Rainbow	Respiration	0.8 -0.18
Sockeye	Respiration	0.2
Sockeye	Arterial tension	<0.33
Sparus macrocephalus	Various histochemical changes	3.6% v/v
Coho	Histochemical	>0.25
Coho	Biochemical	<0.33
Coho	Plasma glucose	0.1 -0.3
Coho	Biochemical (200 days)	<0.1
Spring	Fish biomass	0.08-0.14
Fish food	Abundance	>0.03
Spring	Fish biomass	>0.03
Aquatic plants	Abundance	>0.05
Insects, fish	Diversity	>0.05
food	Abundance	>0.05
Spring	Fish biomass	>0.05
Coho	Swimming	0.15
Lobsters	Avoidance	>20% v/v
Atlantic Salmon	Avoidance	50% v/v
Oysters	Embryo deformity	0.6% v/v
		Sulfite Mill Effluents*
Freshwater shrimp	Growth	<1.6% v/v
Oysters	Pumping	55
Oysters	Embryonic development	6-12

*Concentrations expressed as % v/v or as fraction of 96-hr LC-50 static bioassay value, unless otherwise noted.

Source: Walden (19)

TABLE 26. RELATIVE TOXIC CONTRIBUTION OF WOOD-DERIVED CHEMICAL COMPOUNDS IN PULP MILL EFFLUENT

		Relative toxic contribution					
			Kraft bleachery				
Type of chemical compound	Specific examples	Kraft pulping	Chlorination	Caustic	Debarking effluent	Mechanical pulping effluent	sulfite pulping effluent
Naturally occurring resin acids	Abietic, dehydro-abietic, isopimaric, levopimaric, palustric, pimaric, sandaracopimaric, neoabietic.	Major	Minor	Major	Major	Major	Major
Chlorinated lignins	-	-	Major	-	-	-	-
Chlorinated resin acids	Mono- and dichioro-dehydroabietic	-	-	Intermediate	-	-	-
Unsaturated fatty acids	Oleic, linoleic, linolenic, palmitoleic	Intermediate	-	-	Minor	-	-
Chlorinated phenolics	Tri- and tetraclor-oguaiacol, Paraclrometa Cresol	-	-	Intermediate	-	-	-
Diterpene alcohols	Pimarol, isopimarol, dehydroabietal, abietal	-	-	-	Minor	Intermediate	-
Juvabiones	Juvabione, juvabiol 1'-dehydroajuvabione, 1'-dehydrojuvabiol, dehydrojuvabione	-	-	-	-	Minor	-
Other acidics	Epoxystearic acid Dichlorostearic acid, Pitch dispersant	-	-	Intermediate	-	-	-
Other neutrals	Abienol, 12E-abienol, 13-epimanool	-	-	-	Minor	-	-
Lignin degradation products	Eugenol, isoeugenol $3,3^1$ dimethoxy, $4,4^1$ dihydroxystilbene	-	-	-	-	-	Intermediate

Source: Walden (19)

TABLE 27. TYPICAL RESIN AND FATTY ACID CONTENTS OF RAW WOOD TYPES

Species	Total resin acids (percent o.d. wood)	Total fatty acids (percent o.d. wood)
Pines	1.5%	1.0%
Other softwoods	0.1%	0.1%
Hardwoods	negligible	0.5%

Source: Swan (48)
o.d. = oven dried

TABLE 28. RESIN ACID CONTENT OF PINUS BANSIANA FOR VARIOUS TREE DIAMETERS

Diameter (inches)	4	8	12	15	20
Total resin acid content (% o.d.wood)	1.55	1.59	2.38	2.91	6.0

Source: Sinclair and Dymond (23)
o.d. = oven dried

Also, for similar wood species some pulping processes, such as groundwood, may extract fewer toxicants than more severe chemical pulping processes. The latter, however, may both extract and degrade a greater amount of toxicants which could result in a similar raw effluent loading. These results illustrate some of the complexities of attempting to characterize the toxic pollutant content of various raw effluents.

Other potentially toxic materials of concern in pulp, paper, and paperboard effluents are heavy metals which can originate from dyes or other chemicals used in papermaking, detergents used for deinking, and PCB's which were formerly used in carbonless copy paper and are still present in some wastepaper mill effluent. Martins, et al (45) determined that the detergents Nalco 808 and Sterox MS-b were lethal to fish at a concentration of 4.0 mg/l.

Reported 96-hr LC-50 concentrations for selected toxic compounds are presented in Table 29.

Conventional and Toxic Pollutants from Other Wood Products Industries

Converted Paper--

This industry is concerned with paper coating and glazing and/or modifying the shape of paper products by processes such as cutting, trimming, and folding. The converted paper industry is excluded from regulation under paragraph 8(a)(iv) of the 1977 Clean Water Act. Process wastewater flow rates are generally low, with the median industry rate estimated at zero. The process wastewater that is discharged is usually measured in tens of gallons per day and is limited to clean-ups in printing, gluing, and coating operations. While potential exists for discharge of heavy metals and other priority pollutants in operations using inks and coating materials, total amounts of priority pollutants discharged are expected to be insignificant because flows are characteristically low. The industry was included in the consent decree because of the presumed potential for PCB discharge. However, the industry has not used PCB's since 1972. PCB's entering the paper cycle today are found only in repulping operations and will be regulated under the secondary fiber subcategories as a result of the pulp, paper, and paperboard BAT review study.

Veneer/Plywood--

Wastewater streams in the veneer/plywood industry include: log pond overflow, hydraulic debarking, log conditioning, veneer dryer wash-up and fire protection, and glue system wash-up. The BOD_5 and TSS load from most of these sources is highly variable due to differing plant practices, fire frequency, etc.

In one mill using urea glue, the loss of glue was estimated at 2,700 kg per million square meters of plywood. The pH of the glue wash-up water was 11. Chemical analyses for various glues are shown in Table 30.

TABLE 29. MEDIAN LETHAL CONCENTRATIONS OF CERTAIN TOXICANTS KNOWN TO BE PRESENT IN VARIOUS PULP AND PAPER MILL EFFLUENTS

Substance (reference no.)	96-hr LC-50, mg/l (Rainbow trout)
Resin acids (49)	
Isopimaric	0.4
Palustric	0.5
Abietic	0.7
Pimaric	0.8
Dehydroabietic	1.1
Diterpene alcohols (49)	
Isopimarol	0.3
Pimarol	0.3
Dehydroabietol	0.8
Abietol	1.8
Chlorinated resin acids (33)	
Monochlorodehydroabietic acid	0.6
Dichlorodeydroabietic acid	0.6
Chlorinated phenolics (33)	
Trichloroguaiacol	0.72
Tetrachloroguaiacol	0.32
Fatty acids (33)	
C_{18}-Unsaturated fatty acid	9
Other acids (33)	
Epoxistearic acid	1.5
Juvabiones (50)	
A^4-Dehydrojuvabione	0.8
Juvabione	1.5
Dihydrojuvabiones	1.8
Juvabiols	2.0
Heavy metals (51)	
Zinc	1.0
Volatiles (19)	
Hydrogen sulfide	0.3-0.7
Methyl mercaptan	0.5-0.9
Sodium sulfide	1.0-1.8

TABLE 30. CHEMICAL ANALYSIS OF GLUES

Type of glue	BOD_5 (mg/kg)	TSS (mg/kg)	Phenols (mg/kg)
Phenolic glue	no data	92,000	514
Protein glue	88,000	89,000	514
Urea glue	195,000	346,000	1,810

Source: U.S. Environmental Protection Agency (2)

From the data shown, protein glue use would appear to have the least impact on effluent quality. No published information was found concerning priority pollutants in the veneer/plywood segment.

Particleboard--

Particleboard manufacture consists essentially of mixing a binder resin with wood particles which had previously been classified and dried. The mixture is then formed into mats which are finished by sanding and trimming to size. A typical particleboard plant produces 270 metric tons per day of particleboard, and discharges on an intermittant basis 11,000 l/day of wastewater. Concentration ranges of pollutants in the wastewater are: 44-300 mg/l BOD_5, 21-260 mg/l TSS, and 0-20 mg/l phenols. The pH varies from 6 to 12. As seen, pollutant emissions are highly variable from mill to mill. No data concerning specific priority pollutant emissions was available.

Millwork, Structural Members, and Fabricated Wood Products--

The only significant effluent from the manufacture of millwork, structural members and fabricated wood products is clean-up from glueing operations. The pollutant loading from these operations is highly dependent on the glue and volume of water used. The levels of reported effluent pollutants are: 1,500 to 2,800 mg/l BOD_5; 15,000 to 47,000 mg/l COD, 2,000 to 16,000 mg/l cobalt; less than 5 mg/l lead. No specific information was found relating flow to production data, however, average flows are reportedly from 0 to 7 liters per employee.

Wood Furniture and Fixtures --

Water usage in the furniture industry is highly variable primarily because its usage is not required on a regular basis. Amounts vary from none for some plants to several thousand gpd for others. Existing end-of-line treatment is primarily a function of plant location. The vast majority of plants are located near municipalities and utilize a municipal treatment system as their disposal method. It has been estimated that 95 percent of all furniture factories either discharge their wastewater to a municipal sewage system, contract them to be hauled away by commercial disposal companies, or use a combination of these disposal methods.(175)

Gum and Wood Chemicals--

The gum and wood chemicals category has been divided into six subgroups: 1. Char and charcoal briquettes, 2. gum rosin and turpentine, 3. wood rosin, turpentine and pine oil, 4. tall oil rosin, pitch and fatty acids, 5. essential oils, 6. rosin derivatives. No data on the emissions of priority pollutants is available from any segment of this category. Table 31 summarizes effluent characteristics of flow, BOD5 and COD for various products within this category.

No significant water emissions are discharged from the char and charcoal briquettes segment. The distillate obtained from the char production by wood decomposition is oxidized, producing air emissions.

The gum rosin and turpentine industry refines crude gum in order to obtain a purified gum rosin and turpentine as a byproduct. Wastewater is generated from washing of the rosin to remove soluble impurities, from distillate condensation, and from brine used to dehydrate the gum rosin. As shown in Table 31, data from two plants shows wide variations in the effluent BOD5 and COD. It was concluded that process control in Plant B is much better than the control in A.

TABLE 31. GUM AND WOOD CHEMICALS EFFLUENT SUMMARY

Product(s)	Flow (kl/kkg)	BOD5 (kg/kkg)	COD (kg/kkg)
Gum rosin & turpentine			
Plant A	0.65	7.88	15.0
Plant B	0.40	0.99	1.79
Wood rosin, turpentine & pine oil	9.47	6.49	12.6
Pitch, rosin, & fatty acids	4.86	3.11	7.08
Wood rosin derivatives			
Plant A	0.22	4.68	9.83
Plant B	0.40	4.11	7.33

Source: U.S. Environmental Protection Agency (176)

The wood rosin, turpentine, and pine oil subgroup extracts those products from shredded pine stumps. Process wastewaters emanate from the stripping, vacuum, steam condensation, and stump washing processes.

The separation of crude tall oil into pitch, rosin, and high-purity fatty acids occur in a highly refined distillation process. Wastewater comes primarily from the acid wash of crude tall oil, with additional wastewater from process washdowns.

Rosin is usually converted to a derivative before use; oxidation, hydrogenation, and polymerization are only a few of the processes used to accomplish this conversion. The wastewater characteristics are dependent upon the process used.

Wood Preserving--

The wood preserving process usually consists of two basic steps. First the wood is preconditioned to reduce moisture content and increase permeability. Once preconditioned, the wood is impregnated with the desired preservative(s). The following information concerning wood preserving wastewaters was derived largely from a report by Environmental Science and Engineering.(6) Wastewater characteristics vary with the particular preservative used, the volume of stock that is conditioned prior to treatment, the conditioning method used, and the extent to which effluents from the retorts are diluted with water from other sources.

Wastewaters from creosote and pentachlorophenol treatments often have high phenolic, COD, and oil concentrations and a turbid appearance that results from emulsified oils. They are always acid in reaction, the pH values usually falling within the range of 4.1 to 6.0. The high COD contents of such wastes are caused by entrained oils from wood extractives, principally simple sugars, that are removed from wood during steam conditioning. The composition of wastewaters from pentachlorophenol and creosote treatment are similar except that the former contain chlorinated phenols, principally pentachlorophenol with dioxins and furans, while the latter contain non-chlorinated phenols and polynuclear aromatic compounds.(52)

Wood preserving wastewaters may also contain increased traces of copper, chromium, arsenic, zinc, and boron at plants that use the same retort for both water-borne salts and oil-type preservatives, or that apply dual treatments to the same stock; i.e., treat with two preservatives, one of which is a salt formulation. Organic priority pollutants in wastewaters from plants which treat with organic preservatives only are principally volatile organic solvents such as benzene and toluene, and polynuclear aromatic components of creosote which are contained in the entrained oils. Specific phenolic compounds identified in these wastewaters include phenol, chlorophenols, and nitrophenols. Raw wastewater data from wood preserving processes are summarized in Tables 32 and 33.

Quantitatively, wastewaters differ greatly among plants, and with time at a given plant. Among the several factors influencing both the concen-

TABLE 32. RAW EFFLUENT DATA FROM CREOSOTE AND PENTACHLOROPHENOL PROCESSES

Waste parameters	Usual range of concentrations* (mg/l = ppm)	Average concentration for 24-hr composite samples for five plants
Total phenolic compounds	100 - 350	137#
Chemical oxygen demand	3,000 - 60,000	17,890#
Biochemical oxygen demand	-,000 - 25,000	8,732#
Oil content	80 - 2,000	176#
Total solids	2,000 - 20,000	11,000#
Total volatile solids	1,000 - 10,000	-
Dissolved solids	1,800 - 18,000	9,000
pH	3.5 - 6.0	5.1#

[*] Units of measure are mg/l for all parameters except pH.
[#] Each value is of the average of from 125 to 250 separate analyses.
Source: Thompson and Dust (52), and Jones and Frank (53)

TABLE 33. RAW EFFLUENT DATA FROM WOOD PRESERVING PROCESSES USING WATERBORNE PRESERVATIVES AND FIRE RETARDANTS

Pollutant	Concentration (mg/l = ppm)
Chemical oxygen demand	10- 50
Arsenic	13- 50
Phenols	0.050- 0.160
Copper	0.05 - 1.1
Chromium (+6)	0.23 - 1.5
Chromium (+3)	0.0 - 0.8
Fluorine	4 - 20
Phosphates	15 - 150
Ammonia as N	80 - 200

Source: U.S. Environmental Protection Agency (2)

tration of pollutants and volume of effluent, the moisture content of the wood prior to conditioning, whether by steaming or Boultonizing, is the most important. Wood water from conditioning accounts for most of the loading of pollutants in a plant's effluent and strongly influences wastewater. The moisture content of the wood prior to conditioning determines the duration of the conditioning cycle.

Rainwater that falls on or in the immediate vicinity of the retorts and work tank area--an area of from about one-quarter to one-half of an acre for the average plant--becomes contaminated and can present a treatment and disposal problem, particularly in areas of high rainfall. For example, a plant located in an area that receives 152 cm (60 in.) of rain annually must be equipped to process an additional 1.5 to 3.0 million liters (400,000 to 800,000 gal.) per year of contaminated water.

Another factor which influences the concentration of pollutants, particularly organic pollutants, is the type of solution or solvent used as a carrier for the preservative (coal tar, oil, etc.).

Wastewaters resulting from treatments with inorganic salt formulations are low in organic content, but contain varying concentrations of heavy metals used in the preservatives and fire retardants employed. The nature and concentration in wastewater of a specific ion from such treatments depend on the particular formulation employed and the extent to which the waste is diluted by washwater and stormwater.

The quantity of wastewater generated by a wood preserving plant is a function of the method of conditioning used, the moisture content of wood to be treated, the amount of rainwater draining toward the treating cylinder, and the quantity of other wastewater streams (such as boiler blowdown, cooling water, sanitary wastewater, water softening exchange regenerant, etc.). Ignoring the amount of dilution from other wastewater streams, the sources and approximate ranges of wastewater generated per unit of production for Boulton and steaming plants (including vapor drying plants) are summarized in Table 34. It should be noted that most wood preserving plants treat stock having a wide range of moisture contents, and often air- or kiln-dry stock. Although most plants will predominantly use one of the major conditioning methods, many plants will use a combination of several conditioning methods. For this reason, the actual quantity of wastewater generated by a specific plant may vary considerably.

PRODUCTION PROCESS CONTROLS TECHNOLOGIES FOR IMPROVED RAW EFFLUENT CHARACTERISTICS IN PULP, PAPER, AND PAPERBOARD CATEGORY

Introduction

As part of the BATEA effluent guidelines development process, specific production controls which could be implemented in each pulp, paper, and paperboard industry subcategory have been identified. The following para-

TABLE 34. WOOD PRESERVING WASTEWATER QUANTITY

Process	Wastewater source	Wastewater quantity*
Steam conditioning		
Open steaming	-	240-1200
Modified closed steaming	-	112
Closed steaming	-	negligible
Vapor drying	Wood-derived	64-128
	Rain water	0-181
Boulton conditioning	Steam condensate	negligible
	Wood-derived	64-192

*Units are shown as kg/cu m of production, approximately the same as liters/cu m.

Source: Environmental Science and Engineering (6)

graphs and tables summarize the applicable controls by subcategory and the main wastewater parameters affected by each. For a technical discussion of each production control, the reader is referred to the Preliminary Data Base Document for the BATEA review.(54)

Pulp, Paper, and Paperboard Production Process Controls

The applicable production process control items fall into nine specific mill areas:

1. woodyard/woodroom;
2. pulp mill;
3. washers/screen room;
4. bleachery;
5. evaporators and recovery;
6. liquor preparation area;

7. papermill;

8. steam plant and utilities; and

9. effluent recycle.

Woodyard/Woodroom--

Production process controls that reduce raw waste loading in the woodroom area include: 1) conversion to mechanical or dry systems or close-up of wet operations with variations in sources of make-up water and means of handling flume overflow and dumping; and 2) the segregation and reuse or direct discharge of uncontaminated cooling waters.

Pulp Mill--

Production process controls that reduce raw waste loading in the pulp mill area include: 1) reuse of digester relief and blow condensates; 2) reduction of groundwood thickener overflow; and 3) spill collection in the brown stock, digester and liquor storage areas.

Brown Stock Washers and Screen Room--

Production process controls that reduce raw waste loading in the washer and screen room areas include: 1) addition of a third or fourth-stage washer; 2) recycle of more decker filtrate; and 3) discharge of cleaner rejects to landfill.

Bleaching Systems--

Bleaching systems vary widely from single stage operations in groundwood and deink mills, to three (CEH) stages in sulfite and semi-bleached alkaline mills, to five stages in a fully bleached alkaline mill. Technologies which are applicable in this area include: 1) installing countercurrent or jump-stage pulp washing systems and 2) evaporating the caustic extraction stage filtrate. The latter technology is especially applicable for the Sulfite-Dissolving subcategory. The hot caustic extraction stage would have a three-stage washing system similar to a red stock washer with carefully controlled hot showers. The effluent from this stage would be evaporated and incinerated separately from the rest of the bleaching effluent; therefore, flow would be kept to a minimum. Implementation of this control will greatly reduce the BOD_5 and TSS loadings.

Liquor Preparation Area--

Production process controls that reduce raw waste loads in the liquor preparation area include installation of a green liquor dregs filter and lime mud pond.

Papermill--

Production process controls that reduce raw waste loading in the papermill area include: 1) papermachine, bleached pulp and color plant spill collection; 2) saveall improvement; 3) high-pressure showers for wire and felt cleaning; 4) whitewater use for vacuum pump sealing; 5) whitewater showers for wire cleaning; 6) whitewater storage for upsets and pulper dilution; 7) recycle of press effluent; 8) reuse of vacuum pump water; 9) provision for additional broke storage; 10) installation of wet lap machines; 11) segregation of cooling water; and 12) collection of cleaner rejects for landfill disposal and/or fourth-stage cleaners.

Steam Plant and Utility Areas--

Production process controls that reduce raw waste loads in the steam plant and utility areas include: 1) segregation of cooling waters; and 2) installation of lagoons for boiler blowdown and backwash waters.

Recycle of Effluent--

Mills in three subcategories can reduce fresh water usage by recycling clarified effluent to the mill for use as hose and pump seal water. These mills are in the Deink, Nonintegrated-Fine, and Nonintegrated Filter and Non-Woven subcategories. The industrial tissue mills may also reduce purchased waste paper requirements through recycle of the clarifier solids to the system. Benefits from clarifier effluent recycle are effluent flow reductions corresponding to the amount recycled. Recycle of clarifier solids yields expected cost savings in the purchased furnish, and in handling and disposal of the remaining solids.

Summary of Production Process Controls

Each of the above technologies has been assessed with respect to its applicability in various subcategories, and the major water quality parameter(s) affected. Technologies believed to be the most cost-effective primarily affect BOD_5 and/or flow reductions. Tables 35 through 37 summarizes the technologies by subcategory applicability.

Effects on Raw Effluent Characteristics

The effects of the production process controls shown in Tables 35 through 37 may vary due to unique conditions in a given mill. Typical flow, BOD_5 and TSS reductions for specific production controls have been estimated from available information. A summary of these anticipated effects is presented in Table 38.

EFFLUENT TREATMENT TECHNOLOGIES

Introduction

Wastewater treatment technologies applicable to the pulp, paper, and paperboard industry and other wood products industries include technologies currently in use, as well as some which are currently being developed. These technologies have been grouped as follows:

- primary treatment processes;

TABLE 35. PRODUCTION PROCESS CONTROLS - INTEGRATED MILLS

	SUBCATEGORY											
Control	Dissolving kraft	Market bleached kraft	BCT bleached kraft	alkaline fine	Un-bleached kraft	Semi-chemical	Unbleached kraft and semi-chemical	Dissolving sulfite pulp	Papergrade sulfite	Ground-wood TMP	Ground-wood CMN papers	Ground-wood fine papers
1. Woodyard/woodroom												
a. Close-up or dry woodyard and barking operation	-	-	-	-	-	-	-	X	-	-	-	X
b. Segregate cooling water	X	X	X	X	X	X	X	X	-	X	X	X
2. Pulp mill												
a. Reuse relief and blow condensates	X	X	X	X	X	-	-	-	-	-	-	-
b. Reduce groundwood thickener overflow	-	-	-	-	-	-	-	-	-	-	-	X
c. Spill collection	X	X	X	X	-	-	-	X	X	-	X	X
3. Washers and screen room												
a. Add 3rd or 4th stage washer or press	X	X	X	X	X	X	X	-	X	-	-	-
4. Bleaching												
a. Countercurrent washing	-	-	-	X	-	-	-	-	X	-	-	-
b. Evaporator caustic extract filtrate	-	-	-	-	-	-	-	X	-	-	-	-
5. Evaporation and recovery areas												
a. Replace barometric condenser	X	-	-	-	-	-	-	-	-	-	-	-
b. Boil out tank	X	X	-	-	-	-	-	-	-	-	-	-
c. Neutralize spent sulfite liquor	-	-	-	-	-	-	-	-	-	-	-	-
d. Segregate cooling water	-	-	-	-	-	X	-	-	-	-	-	-
e. Spill collection	X	X	X	-	-	-	-	-	-	-	-	-
6. Liquor preparation area												
a. Spill collection	X	-	-	X	-	-	-	X	X	-	-	-
b. Spare tank	X	X	X	X	-	-	-	-	-	-	-	-
7. Paper mill												
a. Spill collection												
1. Paper machine and bleached pulp spill collection	X	X	X	X	-	-	-	X	X	X	X	X
2. Color plant	-	-	-	X	-	-	-	-	-	-	-	X
b. Improve saveall	-	-	-	-	-	-	-	-	-	-	-	-

TABLE 35. (Continued)

	SUBCATEGORY											
Control	Dissolving kraft	Market bleached kraft	BCT bleached kraft	Alkaline fine	Un-bleached kraft	Semi-chemical	Unbleached kraft and semi-chemical	Dissolving sulfite pulp	Papergrade sulfite	Ground-wood TMP	Ground-wood CMN papers	Ground-wood fine papers
7 Paper mill (cont.)												
c. High pressure showers for wire and felt cleaning	X	-	-	-	-	-	-	X	-	-	-	-
d. White water use for vacuum pump sealing	X	-	X	X	-	-	-	X	X	-	X	X
e. Paper machine white water showers for wire cleaning	-	-	-	-	-	-	-	-	-	-	-	-
f. White water storage for up-sets and pulper dilution	-	-	-	-	-	-	-	X	-	-	X	-
g. Recycle press water	X	-	-	-	X	X	-	-	X	-	X	X
h. Reuse of vacuum pump water	-	-	-	X	X	X	X	X	X	-	X	X
i. Broke storage	-	-	-	-	-	-	-	-	-	-	-	-
j. Wet lap machine	-	-	-	X	-	-	-	-	X	-	-	-
k. Segregate cooling water	-	-	-	-	-	-	-	-	-	-	-	-
l. Cleaner rejects to landfill	-	-	-	-	-	-	-	-	-	-	-	-
8. Steam plant and utility areas												
a. Segregate cooling water	X	-	-	-	-	-	-	X	-	-	-	X
b. Lagoon for boiler blowdown & backwash waters	X	X	X	X	-	-	-	-	X	-	-	-
9. Recycle of effluent	-	-	-	-	-	-	-	-	-	-	-	-

Source: Edward C. Jordan Co., Inc. BATEA Review Program

TABLE 36. PRODUCTION PROCESS CONTROLS SECONDARY FIBER MILLS

	SUBCATEGORY				
Control	Deink	Tissue from wastepaper	Paperboard from wastepaper	Wastepaper molded products	Builders' paper and foofing felt
1. Woodyard/woodroom					
a. Close-up or dry woodyard and barking operation	-	-	-	-	-
b. Segregate cooling water	-	-	-	-	-
2. Pulp mill					
a. Reuse relief and blow condensates	-	-	-	-	-
b. Reduce groundwood thickener overflow	-	-	-	-	-
c. Spill collection	X	-	-	-	-
3. Washers and screen room					
a. Add 3rd or 4th stage washer or press	-	-	-	-	-
4. Bleaching					
a. Countercurrent washing	-	-	-	-	-
b. Evaporator caustic extract filtrate	-	-	-	-	-
5. Evaporation and recovery areas					
a. Replace barometric condenser	-	-	-	-	-
b. Boil out tank	-	-	-	-	-
c. Neutralize spent sulfite liquor	-	-	-	-	-
d. Segregate cooling water	-	-	-	-	-
e. Spill collection	-	-	-	-	-
6. Liquor preparation area					
a. Spill collection	-	-	-	-	-
b. Spare tank	-	-	-	-	-

TABLE 36. (Continued)

	SUBCATEGORY				
Control	Deink	Tissue from wastepaper	Paperboard from wastepaper	Wastepaper molded products	Builders' paper and roofing felt
7. Paper mill					
a. Spill collection					
1. Paper machine and bleached pulp spill collection	-	-	-	-	-
2. Color plant	-	-	-	-	-
b. Improve saveall	-	-	-	-	X
c. High pressure showers for wire and felt cleaning	X	-	-	-	-
d. White water use for vacuum pump sealing	X	-	-	-	-
e. Paper machine white water showers for wire cleaning	-	-	-	-	X
f. White water storage for upsets and pulper dilution	-	-	X	-	-
g. Recycle press water	-	-	-	-	-
h. Reuse of vacuum pump water	-	-	-	-	-
i. Broke storage	-	-	-	-	-
j. Wet lap machine	X	-	-	-	-
k. Segregate cooling water	-	-	-	-	-
l. Cleaner rejects to landfill	-	X	-	-	-
8. Steam plant and utility areas					
a. Segregate cooling water	X	-	-	-	-
b. Lagoon for boiler blowdown and backwash waters	X	-	-	X	-
9. Recycle of effluent	-	X	-	X	X

Source: Edward C. Jordan Co., Inc. BATEA Review Program.

TABLE 37. PRODUCTION PROCESS CONTROLS
NONINTEGRATED MILLS

	SUBCATEGORY				
Control	Nonintegrated fine papers	Nonintegrated tissue papers	Nonintegrated lightweight	Nonintegrated filter and nonwoven	Nonintegrated paperboard
1. Woodyard/woodroom					
a. Close-up or dry woodyard and barking operation	-	-	-	-	-
b. Segregate cooling water	-	-	-	-	-
2. Pulp mill					
a. Reuse relief and blow condensates	-	-	-	-	-
b. Reduce groundwood thickener overflow	-	-	-	-	-
c. Spill collection	-	-	-	-	-
3. Washers and screen room					
a. Add 3rd or 4th stage washer or press	-	-	-	-	-
4. Bleaching					
a. Countercurrent washing	-	-	-	-	-
b. Evaporator caustic extract filtrate	-	-	-	-	-
5. Evaporation and recovery areas					
a. Replace barometric condenser	-	-	-	-	-
b. Boil out tank	-	-	-	-	-
c. Neutralize spent sulfite liquor	-	-	-	-	-
d. Segregate cooling water	-	-	-	-	-
e. Spill collection	-	-	-	-	-

TABLE 37. (Continued)

	SUBCATEGORY				
Control	Nonintegrated fine papers	Nonintegrated tissue papers	Nonintegrated lightweight	Nonintegrated filter and nonwoven	Nonintegrated paperboard
6. Liquor preparation area					
a. Spill collection	-	-	-	-	-
b. Spare tank	-	-	-	-	-
7. Paper mill					
a. Spill collection					
1. Paper machine and bleached pulp spill collection	X	X	-	X	-
2. Color plant	X	-	-	-	-
b. Improve saveall	-	-	X	X	-
c. High pressure showers for wire and felt cleaning	X	-	X	X	-
d. White water use for vacuum pump sealing	X	-	X	-	X
e. Paper machine white water showers for wire cleaning	-	-	-	X	X
f. White water storage for upsets and pulper dilution	-	-	X	-	-
g. Recycle press water	-	-	-	-	X
h. Reuse of vacuum pump water	X	-	-	-	X
i. Broke storage	-	-	X	-	-
j. Wet lap machine	-	-	-	-	-
k. Segregate cooling water	X	X	X	-	-
l. Cleaner rejects to landfill	-	-	-	-	-
8. Steam plant and utility areas					
a. Segregate cooling water	-	-	-	X	X
b. Lagoon for boiler blowdown and backwash waters	X	X	X	-	-
9. Recycle of effluent	-	-	X	X	X

Source: Edward C. Jordan Co., Inc.BATEA Review Program

TABLE 38. EFFECTS OF PRODUCTION PROCESS CONTROLS ON RAW WASTEWATER CHARACTERISTICS

	Anticipated raw effluent reduction			
Mill area - technology	Flow	BOD5	TSS	(Ref. No.)
	(kl/kkg)	(kg/kkg)	(kg/kkg)	
Woodyard/woodroom				
Closed cycle or dry	8.3 -12.5	-	5 -10	(55,56)
Segregate cooling water	1.25- 4.17	-	-	(57)
Pulp mill				
Reuse relief & blow condensates	0.9 - 3.0	-	-	(58,59, 60)
Reduce groundwood thickener overflow	16.6	-	5.0	(61)
Spill collection		1.5-3.5		(62)
Brown stock washers and screen room				
Add 3rd or 4th Stage	-	1.0-4.0	-	(63,64, 65)
Recycle more decker filtrate	4.2	0.5-1.0	-	(66,67)
Cleaner rejects to landfill	-	-	2.0-3.0	(54)
Bleaching systems				
Countercurrent or jump stage wash	9-29	-	-	(60,68, 69)
Caustic extract evaporation	-	25	substantial	(71)
Evaporation and recovery				
Condensate recycle	-	0.25-1.5	-	(64,67, 72,73)
Replace barometric condenser	<4.2	>0.5	-	(60,74)
Boilout tank	-	-	-	(54)
Neutralize spent sulfite liquor*	-	1.0-1.5	-	(54)
Neutralize spent sulfite liquor#	-	25.0	-	(54)
Segregate cooling water	1.7	-	-	(61,70)
Spill collection	-	substantial	substantial	(64,75, 76)

TABLE 38. (Continued)

	Anticipated raw effluent reduction			
Mill area - technology	Flow	BOD5	TSS	(Ref. No.)
	(kl/kkg)	(kg/kkg)	(kg/kkg)	
Liquor preparation area				
Green liquor dregs filter	-	-	5.0	(56)
Lime mud pond	-	-	1.5-2.5	(65)
Papermill				
Spill collection	-	2.0-2.5	2.0-2.5	(54)
Saveall improvement	0.8-41.7	-	-	(67)
High pressure showers	substantial	-	-	(67,70, 73,77, 78)
Whitewater for vacuum pump seal	substantial	-	-	(54)
Whitewater for showers	Variable	-	-	(54)
Excess whitewater storage	-	substantial	substantial	(54)
Recycle press water	-	substantial	substantial	(54)
Reuse vacuum pump water	21.0	substantial	substantial	(54,55)
Add broke storage	-	-	10.0	(54)
Install wet lap machine	-	-	substantial	(54)
Segregate cooling water	4.0	-	-	(54)
Cleaner rejects to landfill	-	-	1.5-5.0	(54)
4th stage cleaners	substantial	-	substantial	(54)
Steam plant & utility area				
Segregate cooling water	substantial	-	substantial	(54)
Lagoon for boiler blow-down				
Effluent recycle	variable	variable	variable	(54)

*Sulfite-papergrade
#Sulfite-dissolving

- secondary treatment processes;
- additional technologies currently in use; and
- technologies currently being developed.

Pollutants primarily removed by selected technologies and the development status of each technology are summarized in Table 39. These technologies, their effectiveness in reducing conventional, toxic, and nonconventional pollutants from industry effluents, and other aspects are discussed below.

Installed Technology

Various forms of primary and secondary treatment currently are widely used in the industry. A summary of currently installed effluent treatment systems in the pulp, paper and paperboard industry is shown in Table 40. The method of discharge and in-place technology for wood preserving, insulation board, and hardboard plants is shown in tables 41, 42 and 43.

Primary Treatment Processes

Introduction--

Primary treatment processes commonly used to reduce organic and inorganic suspended solids include: sedimentation lagoons, mechanical clarifiers, and dissolved air flotation. The efficiency of primary treatment may be enhanced by the addition of chemical coagulants.

Sedimentation Lagoons--

Where ample suitable land is available, simple sedimentation basins provide an economical means of primary treatment. These earthen basins typically do not exceed 5-ft in depth and are narrow enough to allow removal of sediment deposits. Hydraulic retention is normally 12 hr, and two basins are often constructed to facilitate dredging.(79)

When properly cleaned, sedimentation lagoons can achieve solids removals similar to the removals achieved using mechanical clarifiers. Settleable solids can be reduced by as much as 95 percent with a 12-hr lagoon. Because a portion of these solids are biodegradable, some BOD_5 reduction is attained, although this reduction is normally less than 20 percent.(80)

The major advantage of sedimentation basins is their low capital cost. However, the operating costs and difficulties associated with dredging the basins tend to offset this advantage. The overall economics of sedimentation basins are highly site-specific, depending largely on suitable land availability and cost.

Mechanical Clarifiers--

This technology is the most widely practiced means of primary treatment in the industry. A clarifier usually consists of a circular concrete tank,

TABLE 39. EFFLUENT TREATMENT TECHNOLOGY SUMMARY

Classification/ technology	Major pollutant(s) removed: BOD5	TSS	Color	Toxic organics	Heavy metals	Development status*
Primary						
Settling lagoon		X				A
Mechanical clarifier		X				A
Dissolved air flotation		X				C
Secondary						
Oxidation basin	X	X		X		A
Aerated stabilization	X	X		X		A
Activated sludge						
Conventional	X	X		X		A
Oxygen	X	X		X		D
Two-stage	X	X		X		C
Contact stabilization	X	X		X		C
Trickling filter	X	X		X		C
Rotating discs	X	X		X		C
Additional Technologies Currently in use						
Chemical clarification	X	X	X	X	X	B/C
Granular filtration	X	X				B/C
Carbon adsorption	X	X	X	X		B/C
Technologies under Development						
Membrane processes						
Reverse osmosis (R/O)	X	X	X	X	X	C
Ultrafiltration	X	X	X	X		C
R/O-freeze concentration	X	X	X	X	X	F
Evaporation	X	X	X	X	X	C
Foam separation				X		D/E
Electrochemical treatment	X		X	X	X	D/E
Ion flotation			X			F
Chemical oxidation	X			X		F
Steam stripping	X			X		C
Resin adsorption	X			X		F

*Development status:
A - Widely used in wood products industry.
B - Widely used in other industries.
C - Limited full-scale use in wood products industry.
D - Limited full-scale use in other industries.
E - Pilot-scale use in wood products industry.
F - Laboratory scale use in wood products industry.

TABLE 40. METHOD OF DISCHARGE AND IN-PLACE TECHNOLOGY FOR THE PULP AND PAPER INDUSTRY

Subcategory	Number of plants	Method of discharge						Treatment scheme - direct discharger							
		Direct	Indirect	Indirect primary	Indirect & direct	Self-contained	Unknown	No external treatment	Primary only	ASB	ASB w/ polishing pond	ASB/w holding lagoon	Activated sludge	Oxidation pond	Other
Dissolving kraft	3	3	-	-	-	-	-	-	-	1	1	-	1	-	-
Market bleached kraft	12	12	-	-	-	-	-	2	-	1	3	1	4	-	1
BCT bleached kraft	9	9	-	-	-	-	-	-	-	4	3	1	-	-	1
Alkaline fine	20	16	3	1	-	-	-	-	-	2	3	6	-	1	4
Unbleached kraft (linerboard)	20	19	1	-	-	-	-	-	1	3	4	1	2	4	4
Unbleached kraft (bag)	8	8	-	-	-	-	-	-	-	3	2	2	1	-	-
Semi-chemical	20	18	2	-	-	-	-	1	-	1	8	-	3	-	5
Alkaline unbleached and semi-chemical	10	9	1	-	-	-	-	-	-	1	5	2	1	-	1
Dissolving sulfite	6	6	-	-	-	-	-	-	1	3	-	-	2	-	2
Papergrade sulfite	15	12	1	-	2	-	-	-	-	-	-	-	3	-	6
Groundwood thermo-mechanical pulp	4	4	-	-	-	-	-	-	-	2	-	-	2	-	-
Groundwood CMN papers	5	2	3	-	-	-	-	-	-	-	-	-	1	-	1
Groundwood fine papers	9	7	2	-	-	-	-	-	-	-	-	-	6	-	1
Integrated miscellaneous*	92	68	13	3	4	2	2	-	6	14	15	3	19	1	10
Deink (fine)	5	3	1	1	-	-	-	-	-	-	1	-	2	-	-
Deink (newsprint)	6	2	3	-	-	-	1	-	-	2	-	-	-	-	-
Deink (tissue)	15	11	2	-	1	1	-	-	3	1	-	1	6	-	-
Tissue from wastepaper	23	13	3	1	-	6	-	2	4	1	3	1	-	-	2
Paperboard from wastepaper	159	46	71	20	-	19	3	3	5	9	12	1	7	-	9
Wastepaper molded products	18	7	8	1	-	1	1	2	3	1	-	-	-	-	1
Builders' paper and Roofing felt	66	10	31	5	-	19	1	-	4	-	2	1	1	1	1
Secondary fiber - miscellaneous*	22	9	6	3	1	-	3	-	4	1	-	-	3	-	1
Nonintegrated fine	45	19	15	4	4	2	1	-	7	4	2	-	2	1	3
Nonintegrated tissue	28	14	11	3	-	-	-	1	9	2	-	-	1	1	-
Nonintegrated lightweight	18	14	4	-	-	-	-	1	4	1	-	-	-	1	7
Nonintegrated filter & nonwoven	14	5	7	2	-	-	-	-	1	-	1	-	1	-	2
Nonintegrated paperboard	16	8	8	-	-	-	-	1	4	-	2	-	1	-	-
Nonintegrated miscellaneous*	38	24	6	2	-	4	2	1	15	-	5	-	1	-	2
TOTAL	706	378	201	46	12	54	14	14	71	57	72	20	70	10	64

*Groupings of miscellaneous mills - not subcategories
Source: Edward C. Jordan Co., Inc.BATEA Review Program

TABLE 41. METHOD OF DISCHARGE AND IN-PLACE TECHNOLOGY FOR WOOD PRESERVING PLANTS RESPONDING TO DATA REQUEST

	Discharge method		
Process	Direct	Indirect	Self-contained
Boulton	0	11	24
Steaming	10*	23	57
Inorganic salt#	1	5	56
Non-pressure	0	0	23
Total	11	39	160

*3 process discharge, 7 storm discharge.

#Current regulations prohibit discharge of process waters from this subcategory, either directly or indirectly.

Source: Environmental Science and Engineering (6)

TABLE 42. METHOD OF DISCHARGE AND IN-PLACE TECHNOLOGY FOR INSULATION BOARD PLANTS RESPONDING TO DATA REQUEST

Ultimate disposal method	Number of plants
Direct discharge	5
Discharge to POTW	6
Self-contained dischargers spray irrigation	3*
No-discharge (plants generating no wastewater or recycling all wastepaper)	2

*One plant uses spray irrigation as a treatment method; however, the effluent from this system is directly discharged.

Source: Environmental Science and Engineering (6)

TABLE 43. METHOD OF DISCHARGE AND IN-PLACE TECHNOLOGY FOR WET-PROCESS HARDBOARD PLANTS RESPONDING TO DATA REQUEST

Ultimate disposal method	Number of plants
Direct discharge	12
Discharge to POTW	2
*Self-contained dischargers spray irrigation (1 plant)	
Total recycle or treated effluent (1 plant)	2

*Two other plants use spray irrigation to dispose of part of their wastewater. One plant spray irrigates a portion of its sludge.

Source: Environmental Science and Engineering.(6)

with a sludge collection mechanism. Effluent enters through a well on the center pier, and settled sludge is raked to a center sump or concentric hopper. Floating matter is skimmed from the surface and discharged to a hopper. Rise rates range from 400 to 600 gpd/ft^2. Side water depths are often 10 to 12 ft. Twin units, each treating half of the flow, are often installed to allow one unit to be temporarily shut down for repairs.

Mechanical clarifiers can typically remove 95 percent of the settleable solids, which may result in a 75 to 95 percent reduction in TSS. Some BOD_5 removal is also achieved, although this is usually less than 20 percent for integrated pulp, paper and paperboard mills. Nonintegrated paper mills may achieve 50 percent or more BOD_5 reduction in primary clarification. This apparently results from a higher suspended to total BOD_5 ratio in nonintegrated mill effluents.(54,71) Easty (31) has recently observed that little reduction of fatty acids, resin acids or their chlorinated derivatives occurs during primary clarification. Polychlorinated biphenyls (PCB's) from a wastepaper tissue mill, however, were reduced from 25 to 2.2 micrograms/liter (mg/l) through primary clarification. Simultaneous TSS reduction was reported as 2,020 to 77 mg/l.(46) It has not yet been established whether reductions occur for other chloro-organic compounds; this phenomenon is undergoing further study as part of future data gathering efforts.

The higher initial cost of a mechanical clarifier tends to be offset by: 1) small space requirements; 2) low maintenance costs; and 3) continuous sludge production, resulting in relative ease of sludge disposal.

Dissolved Air Flotation--

This process consists of adding air to the effluent while under pressure in an aeration tank. The aerated effluent is then transported to the flotation unit, which is at atmospheric pressure. This reduction in pressure causes bubbles to form and float to the surface carrying wood fibers and other suspended matter with them. The particles so removed accumulate at the surface, where they are collected by skimmers.(81)

Total suspended solids reductions of up to 98 percent are attainable with dissolved air flotation on paperboard from wastepaper mill effluents.(54) Dissolved air flotation is a high-rate process capable of achieving excellent TSS removal. High capital and operating costs are a relative disadvantage, however. High costs combined with sensitivity to variations in pH, temperature, solids concentration, and flow cause the process to be unsuitable for large-scale use.(71)

Secondary Treatment Processes

Introduction--

Currently the most common secondary treatments used in the industry are oxidation basins, aerated stabilization basins (ASB), and activated sludge basins (AS). Other processes in use include two-stage activated sludge (Zurn-Attisholz), rotating biological contactors (RBC), and trickling filters.

Secondary treatment principally reduces BOD_5 in the effluent. This is accomplished through bio-oxidation of organics in the waste. This conversion produces cells which contribute to the TSS content, and must be removed prior to discharge. The rate of bioactivity is temperature-dependent, with high-rate systems being less affected by ambient air temperature.(6)

Substantial toxic pollutant reduction is also achievable through secondary treatment, owing to the biodegradability of major toxic compounds. In a laboratory study, specific biodegradabilities of six toxic pollutants were determined.(82) The compounds, in decending order of relative degradability were: dehydroabietic acid, pimaric acid, tetrachloroguaiacol, monochlorodehydroabietic acid, dichlorodehydroabietic acid, and trichloroguaiacol. The researchers observed that chlorinated bleach plant derivatives were more difficult to degrade than nonchlorinated wood-derived toxic compounds.

Oxidation Basins--

The earliest biological treatment systems used in the pulp, paper and paperboard industry were oxidation basins. These are large natural or manmade basins of various depths; natural aeration from the atmosphere is relied on as an oxygen source. Since oxidation through natural aeration results in a relatively low-rate process, large land areas are required to implement this technology. Because of availability of land and a warm climate that increases bioactivity, most oxidation basins are found in southern states. This technology can be more effective if settleable solids are removed from the wastewater before it enters the basins, since solids can contribute to the BOD_5 wastewater loads and an excess of settleable solids would tend to rapidly fill the basins. Typical design BOD_5 loads range from 56 to 67 kilograms per hectare (kg/ha) of surface area/day (50 to 60 lb/acre/day).(54) Retention times can vary from 20 to over 60 days.(54)

Storage oxidation basins may remove more than 90 percent of the BOD5 load during the summer months if the influent loading is less than 50 lb of BOD5/acre/day. When the BOD5 loads are high, the efficiency of removal drops to 60 or 70 percent. Although a shallow basin or series of shallow basins may remove up to 150 lb of BOD5/acre/day, the high BOD5 loadings associated with such high removals may also lead to odor production. A 175-acre basin in use at a bleached kraft mill reduced the BOD5 concentration from an influent value of 108 mg/l to an effluent value of 36 mg/l. Retention time was 35 days and the resultant removal efficiency was 67 percent.(83) Generally, suspended solids are effectively removed in oxidation basins. Literature presenting data on the removal of toxic and nonconventional pollutants through application of oxidation basin technology is limited.

Due to absorption onto biological solids, biological treatment may yield some color reduction. Although the activated sludge process gives the greatest color reduction, storage oxidation may result in removal of less than 10 percent of the color present depending on the influent color concentrations.(83)

Storage oxidation basins are reliable and are not greatly affected by fluctuations in flow rate and pollutant concentration. They involve low capital and operating costs and require little or no regular personal supervision. These basins, however, require large areas of available land and fairly high ambient temperatures in order to operate efficiently. The land involved must also be fairly resistant to drainage into underground water sources to avoid pollution of such sources by the mill effluent. Basin design often requires 40 to 50 acres of basin area per mgd of mill effluent.(83) Another potential disadvantage is that if the basin should become anaerobic due to insufficient oxygen transfer, objectionable odors may result.

Aerated Stabilization Basins (ASB)--

The aerated stabilization basin (ASB) evolved from the necessity of increasing performance of existing oxidation basins due to increasing effluent flows and/or more stringent water quality standards. Induced aeration provides a greater supply of oxygen, thus substantially reducing the retention time required to achieve treatment comparable to that attained in an oxidation basin. Nitrogen and phosphorus (nutrients) are usually added prior to the ASB if the wastewater is determined to be nutrient deficient. These additions are commonly made in the form of ammonia and phosphoric acid. The longer the retention period of the waste undergoing biological oxidation, the lower the nutrient requirement. The specific detention time used depends upon the characteristics of the wastewaters to be treated.

Aeration is normally accomplished using either gear-driven turbine type surface aerators or direct-drive axial flow-pump aerators. Diffused air can also be employed. Oxygen transfer efficiencies under actual operating conditions range from 0.61 to 1.52 kilograms (kg) of oxygen per kilowatt-hour (kWh), or about (1.0 to 2.5 lb of oxygen per horsepower-hour) depending on the type of equipment used, the amount of aeration power per unit lagoon volume, basin configuration, and the biological characteristics of the system.(87,88) It is necessary to maintain a dissolved oxygen (DO) level of 0.2 to 0.5 mg/l in the basin to sustain aerobic conditions.

Some solids accumulate in the bottom of ASB's, but these are relatively inert and can be removed with periodic dredging. Solids accumulation diminishes as the detention time and degree of mixing within the basin increases. At some mills a settling basin or clarifier is used to improve effluent clarity.

Retention times of 8 to 10 days, and sometimes up to 15 days, have been used in order to obtain BOD5 levels of less than 30 mg/l.(84,85,86) Removal efficiencies for properly designed basins are typically 80 percent or greater.

The removal efficiency of an ASB treating unbleached kraft waste was evaluated over a one-month period in late 1976.(11) Although the raw wastewater exhibited an LC-50 of from 1 to 2 percent by volume, all but one of the 26 treated effluent samples were either nontoxic or exhibited greater than 50 percent fish survival after 96 hours of exposure. The one failure was attributed to a black liquor spill at the mill. Average reductions of 87 percent BOD5, 90 percent toxicity and 96 percent total resin acids were achieved. Dehydroabietic acid was the only resin acid identified in the treated effluent; pimaric, isopimaric and abietic acids tended to concentrate in the foam.

Pilot-scale ASB treatment of bleached kraft wastewater was evaluated over a 5-month period. Two basins, one with a 5-day and one with a 3-day hydraulic detention time, were studied with and without surge equalization. The raw wastewater BOD5 varied from 108 mg/l to 509 mg/l and was consistently toxic. The median survival times (MST) of fish ranged from 7 to 1,440 minutes, while total resin and fatty acid concentrations ranged from 2 to 8 mg/l.(89) Mean BOD5 removals with surge equalization were 85 percent for the 5-day basin and 77 percent for the 3-day basin. Mean effluent BOD5 levels with surge equalization were 40 mg/l for the 5-day basin and 59 mg/l for the 3-day basin. Detoxification was attained 98 percent of the time by the 5-day basin with surge equalization, and 85 percent of the time by the 3-day basin with surge equalization. Mean reported effluent BOD5 values for the 5-day and 3-day basins without equalization were 51 mg/l and 67 mg/l, respectively. The detoxification rate without equalization dropped to 73 percent for the 5-day basin and 70 percent for the 3-day basin. The authors concluded that surge equalization appeared to have a more significant effect on detoxification than BOD5 removal.

Due to adsorption onto biological solids, some color reduction may occur in an aerated stabilization basin. Color removal is typically less than 10 percent, depending on influent concentrations.(83)

Aerated stabilization basins provide a high degree of $BOD\underline{5}$ reduction and also can remove or reduce the wastewater toxicity. ASB capital and operating costs may be lower than those for the activated sludge process. The treatment efficiency is not as dependent on ambient air temperature as with oxidation basins; however, efficiency can be more dependent on ambient air temperature for ASB's than for higher-rate processes (i.e., activated sludge).

The major advantages of the aerated stabilization basin over the oxidation basin are: 1) lower land requirement; and 2) better performance in low temperature conditions. Although ASB capital and operating costs exceed those for storage oxidation, they are usually less than those for activated sludge.

Aerated stabilization basins exhibit good surge capacity due to their relatively long detention times. Although solids sometimes accumulate, the amounts involved are substantially less than those associated with activated sludge processes.

For effluents containing identifiable amounts of heavy metals or other toxic materials the possibility of leaching through the base of an unlined aeration basin to the groundwater exists. The retention of metals in soil increases with increasing clay content, hydrous oxides, pH and surface area per unit weight of soil.(90) Heavy metals with highest soil mobility have been reported to be chromium, mercury, and nickel. Those with lowest soil mobility are lead and copper. Mobility varies for arsenic, berrylium, cadmium, selenium, and zinc.(90) Heavy metal leaching poses the greatest potential concern in wood preserving wastes from plants using heavy metal salts in their process.

In the same study, COD and TOC were found to be not retained well by soil.(90) This would imply that toxic organics which leach through the sediment of an unlined lagoon may enter the groundwater table. No available information was found to document this effect or report any specific cases of related impacts. Any such effect, however, may be eliminated by lining the lagoon with an impermeable material.

Activated Sludge Process--

The activated sludge process is a high-rate biological wastewater treatment system. The biological mass grown in the aeration tanks is settled in a secondary clarifier and a portion returned to the aeration tanks, building up a large concentration of active biological material. There can be 3,000 to 4,000 mg/l of active sludge mass in the aeration basin section associated with an activated sludge system, as opposed to the 50 to 200 mg/l common to aerated stabilization basins. Loadings in excess of 130 kg of $BOD\underline{5}$ per 100 liters (100 lb of $BOD\underline{5}$ per 1,000 cu ft) of aeration capacity per day are sometimes used, allowing for relatively small aeration tanks.

Since biological organisms are in continuous circulation throughout the system, complete mixing and suspension of solids in the aeration basin are required. Mechanical surface aerators similar to those used in aerated stabilization basins are normally used; diffused air can also be used.

The contact stabilization process is a variation of the activated sludge process in which two aeration steps are used rather than one. The incoming wastewater is contacted for a short period with active organisms prior to sedimentation. Settled solids are then aerated for a longer period to complete waste assimilation.

A conventional activated sludge system with 6 to 8 hours detention can typically achieve over 80 percent BOD_5 removal, although removal efficiency is dependent in part on influent loading.

Due to the high concentration of biological solids in this process, greater color removal may be achieved than with aerated stabilization basins. A 10 to 30 percent color removal has been observed for activated sludge.(83)

The ability of activated sludge basins to detoxify bleached kraft mill effluents was analyzed over a 5-month period.(89) Two pilot-scale activated sludge systems (8-hr and 24-hr detention) were operated with and without surge equalization. Raw wastewater BOD_5 varied from 108 to 509 mg/l. The raw wastewater was consistently toxic. Reported raw wastewater median survival times (MST) to fish ranged from 7 to 1,440 minutes. Total resin and fatty acid concentrations in the raw wastewater ranged from 2 to 8 mg/l. Mean BOD_5 removals for the 8-hr and 24-hr activated sludge lagoon with a 12-hr surge equalization basin achieved an average of 76 percent and 72 percent BOD_5 removal, respectively. Effluent BOD_5 concentration for the 24-hr system ranged from 5 mg/l to 263 mg/l, with a mean of 64 mg/l. The 24-hr system detoxified the effluent 76 percent of the time.

The 8-hr activated sludge system removed an average of 72 percent of the BOD_5. Final effluent BOD_5 concentrations ranged from 14 to 270 mg/l with a mean of 64 mg/l. The effluent was detoxified 72 percent of the time.(90) The 24-hr activated sludge system, when operated without equalization, was subjected to more vigorous mixing plus addition of 10 mg/l alum. Under these conditions, an average of 90 percent BOD_5 removal was obtained and detoxification was achieved 100 percent of the time. The 8-hr activated sludge system, when operated without surge equalization, was also subjected to more vigorous mixing with no addition of alum. Under these conditions, an average of 84 percent BOD_5 removal was obtained, although detoxification was attained only 55 percent of the time.(89) The authors concluded that equalization did not affect BOD_5 removal efficiency, but improved the detoxification efficiency by 15 to 30 percent. Addition of alum to the activated sludge system appeared to reduce toxicity. The authors speculated that the mechanism of toxicity removal was a chemical reaction.(89) Failures to detoxify were attributed in some instances to hydraulic shocks, black liquor spills or inadequate treatment system operation, although in many instances, the cause could not be determined.(89)

The characteristically short detention times tend to make the activated sludge process more susceptible to upset due to shock loads. When the process is disrupted, it may require several days for biological activity to return to normal. Particular operator attention is required to avoid such shock loadings at mills using this process. This effect can be avoided through provision of sufficient equalization to minimize the effects of shock loadings.

Compared with aerated stabilization basins, the activated sludge process has less shock load tolerance, greater solids handling problems, and higher costs. However, the activated sludge process requires less land than ASB's and is less temperature dependent. Thus it may be preferred in cases where sufficient land for ASB installation is either unavailable or too expensive, and/or cold weather conditions prohibit use of an ASB.

Pure Oxygen Activated Sludge Process--

The pure oxygen activated sludge process uses oxygen, rather than air, to stimulate biological activity. This scheme allows for a lesser detention time and lower aeration power than activated sludge; however, additional power is required for oxygen generation which may result in a net increased power requirement. Solids volumes that must be dewatered and disposed of are similar to those produced by air activated sludge systems.

Field test data by Union Carbide Corporation confirms that the oxygen activated sludge process is capable of achieving final effluent BOD5 concentrations on the order of 20 to 30 mg/l with pulp, paper, and paperboard mill wastes.(91) Effluent TSS after clarification was generally in the range of 40 to 60 mg/l.(91) A summary of pilot scale information is presented in Table 44.

TABLE 44. OXYGEN ACTIVATED SLUDGE TREATABILITY - PILOT SCALE

Production process	Retention (hr)	BOD5 (mg/l) Influent	BOD5 (mg/l) Effluent	TSS (mg/l) Influent	TSS (mg/l) Effluent
Alkaline-unbleached	1.3-2.2	277-464	20-41	57-86	46-61
Alkaline-unbleached	1.8-3.0	214-214	16-22	123-123	36-36
Alkaline-unbleached	2.0-2.9	265-300	25-30	95-120	60-70

Source: Union Carbide Corp.(91)

Sulfite/newsprint effluent was treated using an oxygen activated sludge pilot plant facility over an 11-month period. BOD5 reductions during this time were over 90 percent. Final BOD5 and TSS concentrations ranged from 23 to 42 mg/l, and from 61 to 111 mg/l, respectively. The effluent from the oxygen activated sludge system was found to be acutely toxic. Total resin acids before and after oxygen activated sludge treatment were 25 and 6 mg/l, respectively. Ammonia was found at levels on the order of 50 mg/l. The treated effluent was air stripped to determine if ammonia was the major cause of the high toxicity. Although air stripping reduced the ammonia concentration to less than 1 mg/l and the total resin acid concentration to 1 mg/l, the effluent remained acutely toxic.(92)

Easty (31) studied two examples of pure oxygen activated sludge systems: one treating an bleached kraft wastewater and the other treating an unbleached kraft pulp mill wastewater. Both significantly reduced all identified pollutants. The pollutants evaluated included resin and fatty acids, their chlorinated derivatives, and chloroform. The first system incorporated an oxygen activated sludge basin with hydraulic detention of 3 hours and 10 minutes and a sludge recycle rate of 35 percent. The pH was maintained between 6.2 and 7.5. It was determined from Easty's data that 43 to 92 percent of identified toxic pollutants were removed, with the chlorinated resin acids exhibiting relatively low removal efficiencies. This is consistent with observed biodegradabilities of the nonconventional pollutants.(82)

The second oxygen activated sludge system operated with a detention time of 3.7 hours and a mixed liquor suspended solid (MLSS) concentration of 2,500 mg/l.(31) Bench-scale alum/polyelectrolyte coagulation followed. The effluent was adjusted to pH 5 with alum and 1 mg/l polyelectrolyte was added. Essentially complete removal of all identified resin and fatty acids was obtained. It should also be noted that initial concentrations in the raw waste were relatively low. Since no data was reported for the oxygen activated sludge system without chemically assisted clarification, the relative effects of each of the two processes on removal efficiencies could not be determined.

A major advantage of the pure oxygen activated sludge process is its smaller space requirement when compared with air activated systems. The relative costs of the two processes may vary and should be evaluated on a case-by-case basis. A disadvantage of the pure oxygen system is a lesser amount of proven experience.

Zurn/Attisholz (Z/A) Process--

The Zurn/Attisholz (Z/A) process is a two-stage activated sludge system. The first stage operates at DO less than 1.0 mg/l and the second stage maintains DO at 4 to 5 mg/l. Nutrient and power requirements for the two-stage system are similar to those for the conventional activated sludge process. A total Z/A detention time of four hours may be required to achieve BOD5 and solids reductions comparable to activated sludge and aerated stabilization systems.

Seven full-scale Zurn/Attisholz systems are currently in use at pulp, paper, and paperboard mills in the United States. These installations treat wastewaters from the following types of manufacturing:

Deink	(5 mills)
Sulfite-papergrade	(1 mill)
Integrated-miscellaneous	(1 mill)

Most of these mills reportedly maintain final effluent BOD$_5$ and TSS concentrations in the range of 20 to 25 mg/l each.(93) One mill reportedly achieves BOD$_5$ and TSS levels in the range of 5 to 10 mg/l each.(93) Another mill also attained a 96 percent BOD$_5$ and 99 percent TSS reduction using the Z/A process.(94)

A pilot study comparing a two-stage to a single-stage activated sludge system has recently been performed. It was concluded that the two-stage system achieved a higher toxicity reduction in treating bleached kraft wastewater than did a single-stage system.(95,96)

In one report, the Zurn/Attisholz system was determined to be less costly than conventional activated sludge, but more expensive than aerated stabilization.(97)

Rotating Biological Contactor (RBC)--

This system involves a series of discs on a shaft supported above a basin containing wastewater. The discs are 40 to 45 percent submerged in the wastewater and are slowly rotated; a biological slime grows on the disc surfaces. Closely spaced 12-ft-diameter discs mounted on a 25-ft shaft can result in 100,000 sq ft of surface area.

Pilot-scale evaluations of the RBC system treating bleached kraft wastewater with an average influent BOD$_5$ content of 235 mg/l have resulted in substantial BOD$_5$ reductions.(98) The degree of removal is related to the hydraulic loading rate, as seen in Table 45.

Sludge production reportedly ranged from 0.3 to 0.5 lb of solids per lb of BOD$_5$ removed.(98)

Two pilot plant evaluations (99) reported essentially complete detoxification of board mill, integrated kraft and magnesium-based sulfite mill effluents. Final effluent BOD$_5$ of 59 mg/l for the kraft mill, 65 mg/l for the board mill, and 338 mg/l for the sulfite mill effluent were reported. Raw wastewater BOD$_5$ levels for these mills were 290 mg/l, 285 mg/l and 1,300 mg/l, respectively. No TSS data was reported.(99) This pilot plant work indicates good toxicity and BOD$_5$ reduction capabilities. To date, mill-scale systems in the United States treating pulp mill wastewater have encountered operating difficulties.

Relative advantages of the RBC system include low space and power requirements. Operating difficulties experienced on a mill scale, however, are a major disadvantage at this time.

TABLE 45. PILOT RBC FINAL EFFLUENT QUALITY FOR BLEACHED KRAFT WASTEWATER

Hydraulic loading rate* (gpd/ft2)	70% of time final effluent BOD5 less than (mg/l)	90% of time final effluent BOD5 less than (mg/l)
3	70	90
2	30	45
1	22	39

*Raw effluent BOD5 = 235 mg/l

Source: Gillespie, et al (98)

Trickling Filters--

Trickling filters represent a means of contacting the waste stream with micro-organisms that can remove the organic BOD5-causing materials from the waste stream. They involve a bed of crushed stone or plastic media onto which the micro-organisms' culture is attached. Stone filters are normally from 3 to 10 ft deep, while plastic media filters may be much deeper due to their lighter weight and better air passage characteristics.(79) The effluent stream trickles down through the bed, and the flow of air through the filter bed maintains aerobic conditions. The BOD5-causing organic materials are consumed by the bacteria, and gases, water, and dissolved solids are given off. Because the solids remain in the effluent stream, the effluent from a trickling filter must be clarified.(83) Trickling filters have been widely used in other industries but have been applied in the pulp and paper industry only to a limited extent. BOD5 removal efficiency of trickling filters is low, and as a result they are often used in combination with other BOD5 removal processes, particularly when cooling of the effluent stream is beneficial. Because the bacteria on the filter media must be kept continuously wet, a recycle to the filter is often provided.

Trickling filters normally can remove 40 to 50 percent of the BOD5 load. BOD5 loadings range from 5 to 300 lb/day of BOD5 per 1000 cu ft of filter media.(79)

Trickling filters may handle large flow rates and high BOD5 loadings. They may be successfully used ahead of the activated sludge process or an aerated stabilization basin to cool the effluent stream and to reduce the

BOD5 load to the major biological treatment process. In the pulp, paper, and paperboard industry there is a danger of plugging the trickling filter due to the presence of fibrous materials in the effluent. Capital costs associated with trickling filters are relatively high.

Anaerobic Contact Filter--

This process involves use of a basin filled with crushed rock or other media. Wastewater is passed through the media at a temperature of 90° to 95°F under anaerobic conditions; detention times of three days are common. Steam stripping, nutrient addition, neutralization and dilution of waste liquor with wash water may be required as pretreatments.

A laboratory study of the process showed that 80 to 88 percent BOD5 removal from sulfite wastewaters to levels as low as 34 mg/l have been achieved.(100) The major advantage of the process is a low solids production (0.08 lb of solids per lb BOD5). This results because methane gas rather than biological solids is the byproduct of anaerobic digestion. The author concludes that the cost for the anaerobic process was approximately the same as that for aerated stabilization.(100)

Partial detoxification of sulfite mill wastewater was obtained in a laboratory study.(100) The anaerobic contact filter altered the LC-50 from 4.5 percent to 7.8 percent by volume for rainbow trout. No specific data concerning toxic pollutants was reported.

Additional Technologies Currently in Use

Introduction--

Dissolved and colloidal materials are not readily removed by primary and secondary treatment. These materials contribute to residual BOD5, suspended solids, and color. The stability of these materials results primarily from electrostatic forces of like charge. Additional treatments including chemical clarification, filtration, and/or carbon adsorption may be employed to further improve effluent quality.

Chemical coagulants such as lime, alum, ferric chloride, and fly ash tend to minimize the electrostatic forces, causing destabilization of the dissolved and colloidal materials. Once destabilized, smaller particles aggregate to form larger particles called flocs. The flocculation process is enhanced by slow mixing and the addition of long-chain polymers. The latter serve as nuclei for floc formation.

Suspended solids which do not readily settle by gravity can be entrapped in a filter bed of granular material. Various filter media and/or grain sizes may be used to improve removals. Also, chemical coagulants may be added prior to filtration to improve removal efficiencies.

Activated carbon employs surface adsorption to remove dissolved and colloidal materials from effluents. The key to this process is an extremely large surface area per unit volume of carbon. Activated carbon may be employed in various forms including granular and powdered.

Alum Coagulation--

Full-scale chemical clarification using alum following activated sludge is currently being used at a groundwood chemi-mechanical mill. According to data provided by mill personnel, alum is added at a dosage of about 150 mg/l to bring the pH to 6.1. This pH has been observed to achieve best results. Polyelectrolyte is also added at a rate of 0.9 to 1.0 mg/l to improve flocculation. Neutralization using NaOH is practiced prior to final discharge to bring the pH within acceptable discharge limits. The chemical/biological sludge is recycled through the activated sludge system with no observed adverse effects on biological organisms. Average reported results for 12 months of sampling data (as supplied by mill personnel) show a raw wastewater to final effluent BOD5 reduction of 426 mg/l to 12 mg/l and TSS reduction of 186 mg/l to 12 mg/l.

As part of an EPA-sponsored study, biologically treated effluent from an alkaline kraft mill was evaluated with alum precipitation on a laboratory scale.(32) Existing full-scale treatment consisted of a primary clarifier, aerated stabilization basin and polishing pond. Twenty-four-hour composite samples of the polishing pond effluent were taken on three separate days. The samples were adjusted to pH 4.6 with alum, and four drops of polymer per liter of sample were added. The results are summarized in Table 46.

Color removal information derived from Olthof for various alum dosages is presented in Table 47.(103)

TABLE 46. RESULTS OF ALUM PRECIPITATION OF BIOLOGICALLY TREATED EFFLUENT

	Polishing pond effluent range (mg/l)	Alum-treated effluent range (mg/l)
Total resin and fatty acids	2.82 - 3.75	undetected
Total chlorinated derivatives	0.43 - 0.45	undetected - 0.04
Chloroform	0.025 - 0.032	0.018 - 0.022
BOD5	43.0 - 51.0	0.0 - 14.0

Source: Leach and Thakore (32)

TABLE 47. SUMMARY OF ALUM COLOR REMOVAL EFFICIENCY

Process effluent	Alum dosage (mg/l) 0 Pt-Co units	150 Pt-Co	150 % Removal	300 Pt-Co	300 % Removal
Alkaline pulp	2,400	1,529	37	270	90
Alkaline board	1,000	720	28	90	91
Wastepaper board	1,220	400	67	200	84
Groundwood news	1,200	600	50	130	91

Source: Olthof (101)

The color removal efficiency varies with effluent type; however, an alum dosage of 150 mg/l reduced color by an average of 45 percent, while a dosage of 300 mg/l achieved an average color removal of 89 percent.

Massive Lime Process--

The massive lime process differs from other color removal processes involving lime. The massive lime process utilizes a large excess of lime, much greater than the stoichiometric amount, to produce a heavy settleable sludge. In the massive lime process, a portion of the effluent stream is used to slake the lime, i.e., allow the formation of $Ca(OH)_2$ from CaO. The rest of the effluent stream bypasses the slaker and flows directly to the reaction tank where the effluent contacts the slaked lime for 5 to 30 minutes. The concentration of lime is kept at 20,000 ppm based on the weight of the effluent. In the reaction tank color bodies in the effluent react with calcium ions. The mixture then flows to a clarifier where the slaked lime and insoluble calcium compounds are settled out. The overflow from the clarifier enters the carbonator where flue gases from the lime kiln containing CO_2 are passed through the effluent. Many of the dissolved calcium compounds such as $CaCO_3$ are removed in the carbonator. The clarified and carbonated effluent flows to the receiving stream. The sludge from the clarifier and the carbonator flows into a sludge storage tank. The sludge is pumped to a vacuum filter where it is concentrated to approximately 50 percent solids. In a kraft mill the sludge is then passed to the causticizing process where the lime in the sludge is recovered. Some make-up lime is needed to replace lime lost in the process. Heat is also required to keep the temperature in the lime slaker at approximately 210°F.

Massive lime treatment has been used on a demonstration scale in an unbleached kraft mill at a flow rate of 530 gpm. In this demonstration the massive lime treatment removed an average of 94 to 95 percent of the effluent color load. For example an effluent with a color load of 14,325 Pt-Co color units before lime treatment was reduced to a color load of 745 Pt-Co color units after lime treatment. This represents a color removal efficiency of 94.8 percent. Color reduction depends on the degree to which dyes in the effluent may be solubilized by treatment with slaked lime.

Treatment of effluent waste by the massive lime processes also results in some BOD_5 removal. BOD_5 reduction may range from 20 to 40 percent. For example, for one type of effluent the BOD_5 level before lime treatment was 300 ppm while the BOD_5 level after treatment was 223 ppm. This indicates a BOD_5 reduction of 25.7 percent.(102)

The major advantage of the massive lime process is that it will remove more than 90 percent of the color present in the effluent stream it treats.

Disadvantages of the process include the following:

- Because of the high concentration (20,000 ppm) of lime required in this process, only a small portion of the mill's total effluent stream may be treated, based on the amount of lime normally used for causticizing the green liquor.
- Foaming has been a serious operating problem in the massive lime process. For this reason care must be taken to reduce all sources of entrainment in the system.
- Because of the massive lime process sludge is used in the mill's causticizing process, it causes a dilution in the cooking liquor concentration of about 15 percent. This means that the mill will have to handle an increased volume of fluids and that the capacity of process equipment will have to be increased.(102)
- Effluent from the massive lime process is alkaline and hot. It must be cooled and neutralized before it is sent to the receiving stream.
- Massive lime treatment causes an increase of mineral solids ($NaCl$, Na_2SO_4, Na_2CO_3) in the effluent stream.

Minimum Lime Process--

This technology utilizes a lime dosage ranging from 1,000 to 2,000 mg/l, as compared with 22,000 mg/l for the massive lime process. Accordingly, heat is not required in the lime slaker. Three variations of the process are described below.

One minimum lime process now in use is operated by the Interstate Paper Corporation in Riceboro, Georgia.(103) This system treats effluent from an unbleached kraft mill and employs no lime recovery system. Lime from a slaker is mixed with the effluent stream ahead of a flocculation tank. The flocculation tank has a detention time of 35 minutes. The effluent stream then passes to a clarifier with a 6-hr detention time. The sludge from the clarifier underflow is pumped to a sludge lagoon. No lime recovery is attempted. The clarifier overflow is saturated with $Ca(OH)_2$ and has a pH of about 12. This effluent stream passes to a natural stabilization pond where the effluent absorbs CO_2 from the atmosphere, and $CaCO_3$ is precipitated. Biological oxidation also occurs in the pond. Typical retention time in the pond is 180 days. Effluent treated by this system consistently had a color level of 125 Pt-Co color units (125 ppm) when a lime dosage of 1,000 mg/l was used. Removal efficiency is reported at 86 percent with a 57 percent reduction in total organic carbon (TOC).

Another minimum lime process is in use at a combined kraft-NSSC mill owned by Continental Can Company, Inc. at Hodge, Indiana.(104) The effluent in this system first flows into a grit chamber which contains a revolving disc trash screen. As the effluent stream flows out of the grit chamber, slaked lime is added, and the mixture flows into a clarifier. The clarifier overflow passes into a carbonation tank, then into a carbonation clarifier in which foam is dissipated by spreading it over the surface. $CaCO_3$ precipitates out in the carbonation clarifier. Sludge from the primary clarifier is pumped to a storage tank and is then dewatered in a centrifuge. Sludge from the carbonation clarifier passes to the mill's causticizing process storage tank and is dewatered on a lime mud filter. The two sludge streams are then combined and sent to the lime kiln. The lime kiln in this process must have 25 percent more capacity than would be needed for the ordinary kraft mill causticizing process. The overflow from the carbonation clarifier passes to a basin where its pH is further lowered by the addition of CO_2. It then flows either to further treatment or to the receiving stream. Lime recovered in the lime kiln is recycled to the slaker.

Effluent treated by this system consistently had a color level of 125 Pt-Co color units (125 ppm) when a lime dosage of 1,000 mg/l was used. Removal efficiency is reported at 86 percent with a 57 percent reduction in total organic carbon.

A third minimum lime process was used at a Georgia Pacific Corporation bleached kraft mill in Woodland, Maine.(71) In this system caustic extraction stage effluent enters a mixing tank where 20 to 200 mg/l of cellulosic fibers, 1,500 to 2,000 mg/l of slaked lime, and polyelectrolytes are added. The mixture then flows to a large primary clarifier. The clarifier overflow is added to other mill effluents before discharge. Sludge from the clarifier is 10 to 15 percent solids and is pumped to a mixing tank. Filtered lime mud is added to this mixing tank to produce a sludge concentration of 23 percent solids. This sludge is then dewatered on a belt filter to 50 percent solids and burned in the lime kiln. The lime is recovered and recycled. The addition of the cellulosic fibers enhances ultimate sludge dewaterability. A 90 percent color reduction is reported for this system when treating bleach plant caustic extraction effluent with a lime dosage of 2,000 mg/l. Effluent color values were reduced from 12,000 Pt-Co color units to 1,300 Pt-Co color units. A 47 to 55 percent BOD_5 reduction was also reported in effluent treated by this system.

Advantages of the minimum lime system over massive lime are a lesser lime requirement and smaller lime recovery system. Also the effluent does not require cooling prior to discharge.

Disadvantages of the minimum lime system include a lesser treatment efficiency and scaling and foaming in the carbonation tank contributing to operating difficulties.

Alternative Coagulants--

Alternative coagulation systems include those using ferric sulfate and fly ash. Jensen and Meloni (105) compared the relative effectiveness of these two systems and alum for treating caustic bleaching extract effluents. The results of tests, which were performed at a kraft mill in Finland, are summarized in Table 48.

All three systems were capable of color reductions comparable to that of lime.

In another study, Olthof and Eckenfelder (108) used ferric sulfate, lime, and alum for effluent color reductions from two bleached kraft mills and one kraft paperboard mill. Their results, as shown in Table 49, indicate both an optimum pH and optimum dosage for each case.

Evaluation of the various sludge characteristics indicated that lime sludge resulted in higher allowable filter loading rates (at least four to five times higher) and a higher percentage of solids in the filter cake. These advantages are partially offset by the resulting larger quantity of sludge to be dewatered.

It was concluded that ferric sulfate used for color removal of pulp and paper mill wastewaters can be an attractive alternative to lime treatment. The optimum dosage of ferric sulfate was only one fourth to one third that of the optimum lime dosage.

Another advantage of using ferric sulfate relates to the high pH and large amounts of calcium in solution when using lime. Common practice is to use an additional treatment step, recarbonation, to reduce the pH and recover the calcium as $CaCO_3$. By using ferric sulfate and alum, this additional treatment step is not required. Neutralization may also not be required, depending upon the buffering capacity of the biological treatment.

Filtration--

Filtration technology was evaluated as part of a recent study conducted for the EPA.(107) Results obtained during this study of nine pulp and paper and other industrial effluents utilizing filtration showed that those facilities not utilizing chemical coagulants achieved final effluent levels of TSS ranging from 5.9 to 35 mg/l with reductions of 45 to 70 percent across the filter. Those using coagulants prior to filtration achieved final effluent TSS levels ranging from 5 to 27.5 mg/l with removals of 52 to 85

TABLE 48. COMPARISON OF ALTERNATIVE COAGULANTS FOR TREATING CAUSTIC BLEACHING EXTRACT EFFLUENTS

	Required dosage (mg/l)		
Color removal	Fly ash	alum	Ferric sulfate
80+%	5,000	1,500	2,500
95+%	20,000	2,000	3,000

Source: Jensen and Meloni (105)

TABLE 49. COLOR REDUCTIONS ACHIEVED USING FERRIC SULFATE, ALUM AND LIME

	Mill Type		
Chemical used	Bleached kraft	Bleached kraft	Unbleached kraft paperboard
Ferric sulfate			
Dosage (mg/l)	500	275	250
% color reduction	92	91	95
Optimum pH	3.5 to 4.5	3.4 to 4.5	4.5 to 5.5
Alum			
Dosage (mg/l)	400	250	250
% color reduction	92	93	91
Optimum pH	4.0 to 5.0	4.0 to 5.0	5.0 to 6.0
Lime			
Dosage (mg/l)	1,500	1,000	1,000
% color reduction	92	85	85
Optimum pH	12.0 to 12.5	12.0 to 12.5	12.0 to 12.5

Source: Olthof and Eckenfelder (106)

percent. At a paperboard mill employing single medium sand filtration without chemical addition, an effluent TSS level of seven mg/l was attained subsequent to filtration.

An EPA-sponsored laboratory study evaluated the efficiency of sand filtration on four pulp, paper, and paperboard mill effluents.(108) A flow rate of 5 gpm/sq ft was used and the results are shown in Table 50.

TABLE 50. SAND FILTRATION RESULTS

Mill no.	Initial TSS (mg/l)	TSS removal (%) w/chem	TSS removal (%) w/o chem
1	110	64	14
2	5.5		36
3	70	71	68
5	60		23

Source: Peterson and Graham (108)

As seen, in one of the two cases where coagulation was not employed prior to filtering, substantially better results were obtained than when coagulants were added. It was explained by the authors that natural coagulation which may have occurred during shipment of samples could have affected the results.

Filtration is an available technology for application in treating pulp, paper and paperboard wastewaters. If properly designed and operated, filtration can yield significant solids removals.

Granular Activated Carbon--

Granular activated carbon has been used for many years by municipalities and industry to purify potable and process water. In recent years it has also been used for removal of organics in industrial and municipal wastewater treatment plants.

The granular activated carbon (GAC) process usually consists of one or more trains of carbon columns, consisting of one or more columns per train. The flow scheme may be down through the column, up through the packed carbon bed or up through the expanded carbon bed.

It is economically advantageous in most granular activated carbon applications to regenerate the exhausted carbon. Controlled heating in a multiple-hearth furnace is currently the best procedure for removing adsorbed organics from activated carbon.

The West Wastewater Treatment plant at Fitchburg, Massachusetts treats combined papermill and sanitary wastes at a 15-mgd chemical coagulation/-carbon adsorption facility.(109) Approximately 90 percent of the flow originates from three papermills, with the remaining 10 percent originating from municipal sanitary wastewater. The industrial wastewater undergoes 5 minutes of rapid mixing and 30 minutes of flocculation prior to mixing with the chlorinated sanitary wastewater. The combined waste is then settled after lime and alum addition. This pretreatment has resulted in a 96 percent suspended solids reduction and a 39 percent BOD_5 reduction. The wastewater is then pumped through granular activated carbon filters that yield a 99 percent suspended solids reduction and 97 percent BOD_5 reduction over the raw effluent. Final effluent concentrations are reported as 5.0 mg/l BOD_5 and 7.0 mg/l TSS. No data has been reported concerning toxicity or toxic pollutant removal/ reduction from the plant.(109)

Since the plant was started up in late 1975, it has been plagued with a number of mechanical and operational problems. As a result, the system has been unable to achieve the removal capabilities predicted after initial operation. The pretreatment facility has consistently yielded a 55 percent BOD_5 reduction and 95 percent TSS reduction. The carbon filters have provided 55 percent BOD_5 reduction and 70 percent TSS reduction of the remaining pollutants after pretreatment. Overall, the system is anticipated to achieve 80 percent BOD_5 reduction and 98 percent TSS reduction once the steady state conditions are met.(185)

Pilot testing by Beak Consultants, Ltd. (110), with laboratory analysis confirmed by B.C. Research, indicates that approximately 80 percent of each of the following resin and fatty acids were removed from raw bleached kraft effluent by application of granular carbon adsorption: pimaric, isopimaric, abietic, dehydroabietic, oleic, linoleic and linolenic. Initial total resin acid content was 10.6 to 12.6 mg/l which was reduced to a total fatty acid content of 2.2 to 3.9 mg/l after treatment. A contact time of 7.5 minutes with a carbon exhaustion rate of 5 to 6 lb/1,000 gallons was employed in the study. Detoxification of the raw woodroom wastewater was successful. However, the authors report that the carbon system did not detoxify whole mill effluent during a simulated black liquor spill, even with a contact time of 30 minutes.

Fahmy (111) evaluated carbon adsorption at the laboratory scale with kraft effluents. Color reductions of 95 percent and 78 percent were achieved for bleachery and whole mill effluents, respectively. The carbon requirement for these removals was 12.5 lb/1,000 gallons.

Capital costs for a 15-mgd carbon adsorption system were estimated at nearly $11 million, while annual operating costs were estimated to be over $5 million (1976 dollars). These costs were based on a carbon contact time of 1.5 hours and flow rate of 4 gpm/sq ft of column area.

Carbon adsorption pilot plant work was performed for four years with unbleached kraft effluent at Pensacola, Florida.(112,113,114) The most economical configuration was determined to be low-level lime addition followed by granular activated carbon adsorption.

Dosages of 4.5 lb of lime and 2.5 lb of carbon/1,000 gallons of effluent were observed to reduce color to below 100 Pt-Co units. This represented over 90 percent color reduction, and treated effluent was able to be reused in portions of the mill.

Capital costs for a 10-mgd system were estimated at $7 million, with operating costs of $.30/1,000 gallons, or approximately $1 million per year (1974 dollars). Operating costs included a credit for reused effluent.

Powdered Activated Carbon--

A recent variation of activated carbon technology consists of the addition of powdered activated carbon to biological treatment systems. The adsorbant quality of carbon, which has been known for many years, aids in the removal of organic materials in the biological treatment unit.(115) This treatment technique also enhances color removal, clarification, system stability, BOD_5 and COD removal.(116,117) Results of pilot testing (118, 119) indicate that this type of treatment, when used as a part of the activated sludge process, is a viable alternative to granular carbon systems. Pilot tests (120) have also shown that powdered activated carbon can be used successfully with rotating biological contactors.

One chemical manufacturing complex has installed a full-scale, 40-mgd powdered activated carbon system that started up during the spring of 1977.(121) This system includes carbon regeneration. The waste sludge, which contains powdered carbon, is removed from the activated sludge system and is thickened in a gravity thickener. The sludge is then dewatered in a filter press prior to being fed to the regeneration furnace. The regenerated carbon is washed in an acid solution to remove metals as well as other inorganic materials. Fresh carbon is added as make-up to replace the carbon lost in the overflow from the activated sludge process or in the regeneration system. The powdered activated carbon is thermally regenerated and acid-washed prior to reuse.(121)

In a follow-up study on the full-scale powdered activated carbon activated sludge plant the average results of three months of data are reported in Table 51. The carbon dosage was 182 mg/l, while the hydraulic retention was 14.6 hours.(122)

TABLE 51. FULL-SCALE "PACT" PROCESS RESULTS ON CHEMICAL PLANT WASTEWATER

Parameter	Raw effluent	Final effluent	Percent reduction
Soluble BOD_5 (mg/l)	504	15.2	95
Color (Pt-Co units)	1,416	311	78

Source: Robertaccio, F.L. (122)

It is noteworthy that the estimated capital costs of using powdered activated carbon vs conventional activated sludge systems for the plant are within 10 percent of each other. Operating cost of the powdered activated carbon system was estimated at approximately 25 percent above that for conventional activated sludge alone.(121)

Evaporation--

Evaporation has been discussed as a pulp mill production process control for liquor recovery. Due to the relatively low effluent flows characteristic of the wood preserving industry, the process is widely used as a treatment technique for achieving zero discharge.(6)

Three types of evaporation systems are used for wood preserving wastewater treatment: 1) spray evaporation; 2) cooling tower evaporation; and 3) thermal evaporation. Spray evaporation is used at Boulton and steaming plants. The process consists of containing the wastewater in lined lagoons with several months storage capacity. The wastewater (plus any rainwater which falls into the lagoons) is sprayed under pressure into the air. The fine aerosol spray evaporates by the relative humidity difference between the atmosphere and the spray evaporation area. Temperature, wind, spray characteristics, and humidity are all factors which affect efficiency of operation. To improve efficiency and reduce air pollution potential, oil content in the wastewater should be minimized prior to evaporation.

Cooling tower evaporation is feasible at Boulton plants only.(6) As wood water vapor is condensed, heat is transferred to the cooling water passing through the surface condenser. Condensed wood water is collected and passed through an oil-water separator. This stream is then used for cooling water, where it picks up heat from the surface condenser. The warm water is then passed through a forced draft cooling tower for evaporation. Sufficient waste heat is usually available from the Boulton process to evaporate all of the wastewater.(6) Heat from an external source is added for peak flows.

Thermal evaporation relies primarily on an external heat source. This process is usually too energy-intensive and expensive to be economically feasible.(6)

Technologies Currently Being Developed

Introduction--

A number of technologies for further reducing pollutant discharge and/or costs of treatment are currently under development. These technologies include: foam separation, electrochemical treatment, ion flotation, air/catalytic/chemical oxidation, steam stripping, ultrafiltration, reverse osmosis, reverse osmosis/freeze concentration, amine treatment, and polymeric resin treatment. The stage of development and results to date are presented in the following paragraphs.

Foam Separation--

This process involves physical removal of surface active substances. This is accomplished by the injection of fine air bubbles into a basin containing the effluent. Surface-active substances in the effluent (e.g., resin acids) are attracted to the large surface area of the air bubbles. The air bubbles cause generation of foam in which surface-active compounds are concentrated. The air bubbles float to the surface, where the resulting foam can be removed. The process works most efficiently when the effluent is adjusted to pH 8.0.(123)

Foam generation techniques have been evaluated on a pilot scale for pulp, paper, and paperboard wastewaters. This is a significant aspect of the process since the air bubble size determines the surface area available for pollutant attraction. Jet air dispersion was found to be the most efficient technique when compared to turbine and helical generation systems.(124)

Black liquor from kraft pulp mills may contain 2 to 3 percent soaps which produce a very stable foam. The technology for foam breaking is available. Commercial systems including turbine and centrifugal processes have been developed which can successfully break this foam. Pilot investigations show turbine foam breaking to be most advantageous for the foam produced.(124) Several full-scale foam separation facilities have been built for the removal of detergents from municipal wastes.(128,129) The Los Angeles County Sanitation District system operated on a flow of 12 mgd at a 7-minute detention. Water reclamation was the primary purpose of the unit, which operated successfully and trouble-free during two years of continuous operation.(123) This system, like other municipal systems, has ceased operation due to regulations that require the use of biodegradable detergents.

Bleached kraft whole mill effluent was analyzed for total resin acid content before and after pilot-scale foam separation.(123) Two mill effluents treated a two-hour detention using a foam pilot unit. The resin acid content in all cases was reduced by between 46 and 66 percent. The range of total resin acid content in the influents and effluents were 2.6 to 5.1 mg/l and 0.1 to 1.0 mg/l, respectively. In all cases the treated effluent was rendered nontoxic to fish.

Pilot studies have been performed using foam separation as a pretreatment for activated sludge and for aerated stabilization treatment of bleached kraft effluent.(89) These studies have shown the detoxification efficiency of biological treatment to improve from 50 to 85 percent of the time without foam separation, to over 90 percent of the time with foam.

Electrochemical Treatment--

Electrochemical treatment technology involves the application of an electrical current to the effluent to convert chloride to chlorate, hypochlorite and chlorine. The chlorine and hypochlorite can oxidize organic compounds and be reduced again to chloride ions. The process then repeats in a catalytic fashion. The oxidation of organic compounds reduces the BOD_5, color and toxicity of the effluent. A significant advantage of the process is that no sludge is produced.

Oher (127) found that whole mill bleached kraft effluent could be reduced in color by 80 percent and caustic extract by more than 90 percent by electrochemical treatment. Utilizing a lead dioxide anode similar effluent results were achieved when compared with a graphite anode. The lead dioxide anode required a fraction of the energy. No toxicity or toxic pollutant data was reported.

In a variation of the process, Barringer Research Limited (128) investigated the use of a carbon fiber electrochemical reactor on kraft caustic bleach extracts. The high surface-to-volume ratio of the carbon greatly decreased reactor volume (a 1.6-mgd unit required a 17-cu m reactor). At an effluent-to-water volume ratio of 60 percent (v/v), toxicity was reported to be reduced from 100 percent mortality in 22 hr (60 percent) to 0 percent mortality in 96 hr. Color reduction of 40.6 percent to 7,720 Pt-Co and BOD_5 and COD reductions of 50 percent and 60 percent, to 540 mg/l and 1,164 mg/l, respectively, were reported. This process is in full-scale use in the mining industry but has had no pilot or mill-scale facility in the pulp, paper, and paperboard industry.(129) The primary drawback of the process is failure of the carbon cell to perform for extended periods.(129)

Another variation to this process involves the use of hydrogen gas bubbles generated in the process to float solids and separate scum. Selivanov (130) found that an electrochemical unit with graphite anodes and stainless steel cathodes could cause coagulation in kraft whitewater. Release of hydrogen bubbles in the process caused solids removal by flotation. Total suspended solids were reduced to 2 to 4 mg/l. No toxicity data was reported.

Herer and Woodard (131) found significant color and TOC reductions in bleaching wastes by application of electrolytic cells using an aluminum anode. Color removals for chlorination and caustic extraction effluents were 92 percent and 99 percent, respectively, while TOC removals were 69 percent and 89 percent, respectively. Specific concentrations, however, were not reported.

Ion Flotation--

This process involves the addition of a surfactant ion of opposite charge to the ion to be removed. The combining of these ions results in a precipitate (the colligend). The colligend is removed by passage of air bubbles through the waste and collection of the resulting floating solids.

Many of the chromophoric (color producing) organics in pulp, paper, and paperboard mill wastewaters are negatively charged, making this process suitable for the removal of color. Chan (132) investigated the process on a laboratory scale. A variety of commercial grade cationic surfactants were tested and Aliquat 221 produced by General Mills was found very effective.

The process removed over 95 percent of the chromophoric compounds from bleached kraft effluents. No specific removals of toxicity or toxic pollutants were reported.

Air, Catalytic, Chemical Oxidation Processes--

Complete oxidation of organics in pulp and paper wastes to carbon dioxide and water is a significant potential advantage of these processes. Partial oxidation, coupled with biological treatment may have economic and/or technical advantages over biological treatment alone.

Past studies of oxidative processes have dealt principally with COD or TOC as a measure of performance. Barclay (133) has done a thorough compilation of related studies, and found that most were performed with wastewater other than those from pulp and paper operations. Some tentative conclusions, though, may still be drawn:

1. Complete oxidation with air can occur under extreme temperature and pressure; high intensity irradiation; with air at ambient conditions with excessive amounts of strong oxidants (O_3, H_2O_2 or ClO_2) or air or oxygen in the presence of catalysts such as certain metal oxides.

2. Sulfite wastes can be partially detoxified by simple air oxidation for a period of seven days.

3. Ozone oxidation achieved only slight detoxification of sulfite wastes after two hours, and partial detoxification after eight hr.(133)

4. Major BOD_5 reductions can only be achieved under conditions similar to those required for nearly complete oxidation.

No data specifically relating to toxic pollutant removal was reported.

Steam Stripping--

Steam stripping involves the removal of volatiles from concentrated streams. Hough (134) reports that steam stripping is capable of removing 60 to 85 percent of the BOD_5 from condensate streams. The ability of the process to remove specific pollutants (including the toxic and nonconventional pollutants) depends on the relative boiling points of the pollutants with respect to that of water (i.e., the pollutants must be volatile). Resin acids have boiling points in the range of 250°C and thus are not readily stripped by the process.(135)

Steam stripping was evaluated for its ability to detoxify condensates from sulfite waste liquor evaporators.(136) This stream accounted for 10 percent of the whole mill effluent toxicity and 28 percent of the total BOD_5 load. Toxicity in the condensate stream was attributed to acetic acid, furfural, eugenol, juviabone and abietic acid. Steam stripping had no observable effect on the toxicity of the stream, although the total organic content was reduced.

Steam stripping of kraft mill digester and evaporator condensates was employed on a mill scale for control of total reduced sulfur compounds and toxicity.(137) The 96-hour LC-50 of the condensate was altered from 1.4 percent to 2.7 percent. Thus, the stream remained highly toxic after steam stripping. The process did remove 97 percent of the total reduced sulfur (TRS) compounds, which may have accounted for some of the toxicity reduction. Production process changes (including minimizing condensate volume, installation of a spill collection system, reduction of fresh water use and conversion to dry debarking), along with steam stripping resulted in a nontoxic effluent.

Ultrafiltration--

Ultrafiltration utilizes membranes of a specified molecular size to treat wastewater. The process relies on an external pressure (e.g., pumping) to input the driving force to the wastewater as it is transported through the membranes. The size opening for the ultrafiltration membrane depends on the size molecules to be removed from the wastewater.

Data is available from Easty (31) for nonconventional pollutant removal of two bleached kraft caustic extraction effluents utilizing two types of ultrafiltration systems. Good removals of epoxystearic and dichlorostearic acids and trichloro-and tetrachloroguaiacol were obtained in each case. Chlorinated resin acids were effectively removed by one system, but not by the other.

The first system employed only one spiral wound membrane, with a surface area of 40 sq ft. Filtration of suspended solids larger than ten micrometers was performed before ultrafiltration. The 7.5-gpm system operated with a pH of 11 to 11.5. The system achieved 50 to 80 percent reduction of chlorinated phenolics and other acidics, but only 0 to 15 percent removal of chlorinated resin acids. The lower percent removals of chlorinated resin acids reflect a low initial concentration of these pollutants in the waste.

The second system treated an effluent volume of 3.3 gpm by a tubular cellulose acetate membrane with a surface area of 12.1 sq ft. The system operated at a pH of 9.5 to 10.5 and inlet and outlet pressures of 220 psi and 100 psi, respectively. Filtration of all particles larger than 10 micrometers was performed prior to ultrafiltration. This system achieved removals of 73 to 93 percent of all chlorinated resin acids, chlorinated phenolics and other acidics.

Color, lignosulfonate, COD, and solids removals from sulfite liquor by ultrafiltration were studied by Lewell and Williams.(138) Removals on the order of 30 to 50 percent were observed for color, lignosulfonate, COD and TSS. No toxicity or toxic pollutant data was reported. Costs (1971) were estimated at $1.50/1,000 gal for a 1.0-mgd permeate flow. It was concluded that ultrafiltration could not compete economically with lime as a means of removing lignosulfonate, color, COD and solids.(138)

Reverse Osmosis--

Reverse osmosis employs pressure to force a solvent through the membrane against the natural osmotic force. This is the same type of process as ultrafiltration except that the membranes used for reverse osmosis reject lower molecular weight solutes. This means that lower flux rates occur, along with a need for higher operating pressure difference across the membrane than those experienced with ultrafiltration.

Reverse osmosis is employed at a midwest NSSC mill producing 272 kkg/day (300 tons/day) of corrugating medium. The system allows the mill to operate a closed whitewater system. Easty (31) reported that the system achieved BOD$_5$ reductions of approximately 90 percent and removed essentially all resin and fatty acids. The 85-gpm reverse osmosis unit employs 288 modules, each with 16.7 sq ft of area provided by 18 cellulose acetate tubes. The system operates at 100 psi and 38°C. During Easty's testing, the whitewater feed contained 300 mg/l TSS and 4,000 to 6,000 mg/l total dissolved solids. Initial resin and fatty acid levels were: abietic, 1.5 mg/l, dehydroabietic, 262 mg/l; isopimaric, 2.75 mg/l; pimaric, 0.82 mg/l; oleic, 4.86 mg/l; linoleic, 7.23 mg/l; and linolenic, 0.27 mg/l. The maximum removal capacity is not known since final concentrations were below detection limits.

Reverse Osmosis/Freeze Concentration--

Reverse osmosis can be followed by freeze concentration whereby the effluent is frozen to selectively remove pollutants. Freeze concentration takes advantage of the fact that when most aqueous solutions freeze, the ice crystal is almost 100 percent water.

This process was evaluated by Wiley (139) on three bleach plant effluents. Reverse osmosis alone resulted in a concentrate stream of roughly 10 percent of the volume of the raw feed. Freeze concentration reduced the concentrate stream volume by a factor of five, while essentially all the impurities were retained in the concentrate. Thus the two processes employed in tandem resulted in a concentrate stream consisting of roughly 2 percent of the original feed volume containing essentially all of the dissolved solids.(139) It was reported that the purified effluent was of sufficient quality that it could be returned to the process for reuse. Wiley did not investigate final disposal of the concentrate.

Amine Treatment--

This treatment is based upon the ability of high molecular weight amines to form organophillic precipitates. These precipitates are separated and re-dissolved in a small amount of strong alkaline solution (whitewater). By so doing, the amine is regenerated for use, with no sludge produced.

The Pulp and Paper Research Institute of Canada (PPRIC) conducted a study (140) to determine the optimum process conditions for employing high molecular weight amines for color, BOD$_5$ and toxicity reductions of bleached kraft mill effluents. While no specific toxic or nonconventional pollutants were reported, whole mill bleached kraft effluent remained toxic after application of the treatment in two reported tests. Likewise, acid bleach effluent could not be detoxified. However, alkaline bleaching wastewater was detoxified in three out of four samples at 65 percent dilution. Final effluent concentrations for BOD_5, COD and color of bleached kraft whole mill wastewater were 80 to 350 mg/l, 380 to 760 mg/l, and 2,670 Pt-Co units, respectively. Reported removals were 10 to 74 percent, 36 to 78 percent and 90 to 99 percent, respectively, using Kemaminest-1902D in a solvent of Soltrol 170.

Polymeric Resin Treatment--

Polymeric resin treatment involves the use of resins in columns to treat wastewater. The process utilizes adsorption and ion exchange mechanisms to remove pollutants from the wastewater. The columns are regenerated after a treatment cycle is completed. Regeneration can be achieved by utilizing an alkaline solution.

The Rhom and Haas process involves the use of amberlite XAD-8 resin to decolorize bleaching effluent after filtration. The resin can be regenerated without producing waste sludge as a byproduct. This regeneration may be accomplished by using mill white liquor.

In one study (141) the adsorption capacity of amberlite XAD-2 resin was compared to Filtrasorb 300 activated carbon. The resin was more effective in removing most aromatic compounds, phthalate esters and pesticides while carbon was more effective at removing alkenes. Neither adsorbant was effective at the removal of acidic compounds. The tests involved use of laboratory solutions of 100 organic compounds at an initial concentration of 100 ug/l.

Another study (142) has shown synthetic resin to be capable of removing a higher percentage of COD from secondary effluent than carbon. Also, resin treated wastewater quality was improved when further treated with carbon, although the reverse was not true. The economics of this system could prove favorable since resin may be regenerated in situ. Thus, total regeneration costs may be more economical than for either system alone since carbon life could be significantly extended.

Elimination of toxic constituents from bleached kraft effluents has been achieved with Amberlite XAD-2 resin.(143,144) Wilson and Chappel (145) have reported that treatment with XAD-2 resin resulted in a nontoxic semichemical mill effluent.

PCP Removal From Wood Preserving Wastes--

Reduction of pentachlorophenol (PCP) by several treatment alternatives has recently been evaluated.(146) The techniques considered include: acid cracking; coagulation; chemical oxidation; solvent extraction; and XAD resin adsorption. The conclusions of this work are summarized in the following paragraphs.(146)

Acid cracking to pH 2.0 followed by filtration can cause significant reductions in PCP where initial concentrations exceed low pH solubility limits (i.e., 15 mg/l). Reductions of PCP to subsaturation limits were observed (i.e., 6 mg/l). This was attributed to PCP adsorption by insoluable matter.

Coagulation with 150 mg/l alum followed by filtering with Whatman #41 paper yielded PCP reductions of 50 to 75 percent, resulting in final effluent concentrations of 3 to 10 mg/l.

Extremely high chlorine demands were observed in chemical oxidation experimentation. Over 3,000 mg/l chlorine addition was required to produce excess. This chlorine addition reduced PCP levels to below detection limits of about 0.05 mg/l. Low pH protected PCP from chlorine oxidation, but did not reduce chlorine demand.

Solvent extraction with moderately polar solvents proved to be effective at reducing PCP levels. For example, PCP concentrations of less than 1 mg/l were routinely achieved with butyl acetate extraction. Kerosene and other less polar solvents were less effective in extracting PCP.

Passing the waste through XAD-2 resin columns consistently reduced PCP to less than 0.05 mg/l. This result was observed for samples both before and after acid cracking and/or coagulation.

NONPOINT SOURCE POLLUTION

Characterization of Nonpoint Sources

Nonpoint pollution originates from diffuse sources rather than piped discharges. Nonpoint pollutants of major concern in silviculture include sediment and chemicals such as herbicides and fertilizers.

Sediment and its nutrients result from erosion of logged areas and access roads from which protective vegetative cover has been removed. The water quality impact of these pollutants can be minimized through proper management while simultaneously reducing adverse aesthetic impacts to the land.

Herbicides and to a lesser extent fertilizers are applied in silvicultural areas to maximize wood yield. Herbicides may have a toxic effect on aquatic life when carried by runoff, or when discharged in effluent after wood processing. Fertilizer nutrients which are not taken up by plants may find their way to receiving waters where they could serve as a food source for aquatic life, and/or alter the trophic condition.

Endeavors to establish the magnitude of these impacts and their relationship to specific practices are relatively recent. This science grew out of the reforestation of abandoned farm lands in the 1920's and 30's to prevent soil erosion, and results were expressed primarily as tons of soil loss per acre. Therefore, these results are not particularly useful in determining water quality impacts.

Within the framework of the Clean Water Act, the EPA and U.S. Forestry Service have initiated research programs to establish meaningful and usable relationships, although it is generally agreed that more work is needed before cause and effect relations for site specific cases can be established. This situation arises primarily from the diffuse and non-continuous nature of nonpoint source pollution, and its dependency on the hydrologic cycle.

The EPA has produced a summary document entitled "Non-point Source Water Quality Modeling in Wildland Management: A State of the Art Assessment".(147,148) More recently, the forest service has produced a handbook evaluating alternative management control strategies for specific site conditions and activities. The handbook, commonly referred to as WRENS (Water Resources Evaluation Nonpoint Sources, Silviculture) explains how to identify suitable controls for a given situation.(149)

Harvesting Impact

The major potential sediment-related impacts on streams occur during harvesting. For example, eight years of data from ten catchments supporting loblolly pine planted to control erosion showed no statistical difference in sediment loading than for mature pine-hardwoods (both showed a mean of 0.007 tons per acre per inch of precipitation).(150) Little overland flow occurs from well-stocked forests, thus most of their sediment yield results from channel erosion.

Among harvesting options, clearcutting has the greatest potential short-term impact on water quality. Long term impacts, however, may be equal or greater for rotation if frequent cutting and use of access roads are practiced. In either case the use of buffer strips and contouring of access roads will lessen the impact.

Skidding can cause higher rates of erosion over a portion of the harvesting area, however, most of the soil movement does not find its way to receiving waters. In one study, erosion was measured from twenty trails created by uphill skidding of hardwood logs on a variety of soils, slopes, and lengths. During the first year soil moved from the trails averaged 0.124 tons/acre-inch. The compacted trails, however, rapidly revegitated-resulting in a second year average loss of 0.023 tons per acre-inch.(151, 152)

Regeneration Impacts

Intensive mechanical site preparation, which is used when converting hardwoods to pine or preparing sites for pine regeneration, presents a serious nonpoint source problem. Site preparation practices include shear-burning, tree-crushing, root-raking, chopping, discing, bedding, chipping, and other techniques used singly or in combination. Some restrictions may be needed, because such practices can bare three-fourths or more of the soil. This kind of exposure and soil compaction can result in sediment-producing overland flows and in large increases during storms. However, the magnitude and duration of the impacts of such practices have not been adequately quantified.

The Southern Forest Experiment Station Forest Hydrology Laboratory is currently measuring the impacts of several widely-used site preparation practices. As expected, stormflow has not been adequately defined. One study involving three methods of intensive mechanical preparation indicates that sediment concentrations has not been adequately defined. One study involving three methods of intensive mechanical preparation indicates that sediment yields during the first year after treatment are comparable to those considered acceptable for agricultural lands. Sediment concentrations after site preparation are expected to decline rapidly; increased water yields are expected to persist longer because of soil compaction.

Chemical Impact

Several groups of chemicals used in the management of forests have biological activity with more or less potential for affecting water quality. The biologically active chemicals used in the management of forests fall into four broad categories: fertilizers, herbicides, insecticides, and rodenticides. These materials are used in specific ways so that they: 1) enhance productivity; 2) focus the productive effort in desirable species; and 3) protect the desirable species from consumption. In the course of use, however, forest management must prevent these chemicals from inadvertently harming the aquatic ecosystem.

The major classes of chemicals are used in considerably different patterns. These affect the likelihood of encountering a significant pollution problem resulting from a given dosage. Quantities applied during an application also differ substantially, leading to variations in local deposits. The range of biological activity and inherent chronic and acute toxicities determine whether a given deposit in water will have a significant biological impact.

Fertilizers are generally very low in toxicity, and the baseline levels in soils are usually much larger than the amounts applied. Fertilizer poses a potential pollution problem only because the materials are soluble at the time of application, leading to a brief period during which nutrients may move into water. The likelihood of contamination actually taking place is influenced by deposition directly in open water, or by the occurrence of high-intensity rainfall immediately after application. When contamination does occur, it poses no special water quality problems unless the water is extremely oligotrophic.

Fertilizers are applied at high rates, but at low frequency and in widely dispersed locations. Treatments have not led to large-scale contamination of river systems. Forest fertilization is also done in established stands, where nutrients are utilized by vegetation shortly after application, and are not lost from the forest system. There is no evidence that application of nitrogen fertilizers has ever led to water concentrations of nitrate approaching the 10 ppm (nitrogen equivalent) water standard set by the EPA to respond to human intoxication concerns. In brief, there appears to be no special reason for modifying existing fertilization concerns. In brief, there appears to be no special reason for modifying existing fertilization methods as they pertain to water quality.

Herbicides are much more widely used than fertilizers in forests. These chemicals were quite specific in their effects on plants, and some of the most widely used materials in forests are registered for use in aquatic weed control at much higher concentrations than are encountered in forest watersheds.

Silvicultural herbicides are usually applied by helicopter in small units. They are usually applied no more than once or twice in the development of a timber crop. Roughly 0.2 percent of the commercial forest lands in the United States is treated in any given year.

Aerial applications of herbicides and their effects on water quality have been studied extensively. At no time in studies of silvicultural use of herbicides has water contamination reached concentrations known to affect the most sensitive aquatic plants or fauna. The only contamination known to be potentially harmful is that of picloram when it enters water upstream from irrigated potatoes or tobacco, and thus far, no damage to crops has been recorded as the result of water contamination. Despite widespread publicity, 2,4,5-T and silvex do not pose a special problem, despite their trace contamination with TCDD (2,3,7,8-tetrachlorobibenzo-p-dioxin). These materials have been the subject of very sophisticated toxicology research, and the technological base for their continued use is stronger than that of any other pesticide.(183)

Insecticides and rodenticides are of special interest because of their ability to injure animals at low dosages. For rodenticides, the amounts are so small, and the applications so confined to baits and burrows that specific concerns for water quality have very low priority. Insecticides, conversely, are applied to large areas with application systems designed to project a diffuse pattern. The chance for incidental contamination of waterways is, therefore, greater than for other types of chemical applications. Moreover, the spectra of activity of insecticides indicates that for most materials, very low levels of contamination in water may result in biological impact. The persistent organo chlorine compounds have the greatest potential for long-term effects.

Insecticides are subject to strict administrative control. Most aerial application projects are cooperatively scheduled over areas large enough to bear the overhead costs of monitoring and careful supervision. Despite this, most of the insecticides in use have the potential for causing serious damage to fish or aquatic insect populations if inadvertently applied directly to open water or if spilled directly into a stream in significant quantities.

In sum, there is abundant evidence that priority for water pollution control in the use of silvicultural chemicals is highest for aerial application of insecticides. Among these, the organo-chlorine compounds warrant special consideration to keep them from entering waterways.

Guidelines for Protection of Water Quality

Methods used to reduce impact of forest chemicals include designation of buffer zones of widths in accordance with the potential hazard posed by the chemical. The rationale behind recommendations for buffer strip widths is based on observed 20-fold decrease of contamination with each herbicide swath width away from the stream and five-fold decrease per swath of low-volume insecticides with winds less than 5 mph. Based on experience with various pesticides, the proposed criteria for water concentrations will be met with a margin of safety when registered rates of application are applied as recommended. In those exceptions where buffer strips are defined in terms of absolute width, the problem being addressed is the physical movement overland or through the soil in subsurface flow, a group of processes not affected by application technology.

To achieve forest production goals without compromising water quality, emphasis is given to the identification of practices that have adverse impacts near water, and substituting less harmful practices. Exceptional conditions under which untreated buffer zones are recommended are identified so that unnecessary loss of productivity can be avoided.

Monitoring will be needed to ensure that the recommendations are a) being observed, and b) effective in maintaining water quality. Monitoring for validation of practices will be the responsibility of state and federal water resources agencies, and operational quality control will be the responsibility of the operator. Monitoring of insecticides, in particular, will be necessary by users on a limited scale to provide a record of the consequences of chemical activity at the point of maximum potential trouble.

In conclusion, biologically important direct impacts from herbicides, rodenticides, and fertilizers will not occur when used as prescribed. And virtually all commercial forest lands adjacent to streams may be managed in ways that include their use without impairing water quality. Insecticides also may be used, but substantial buffer zones and greater operational quality control and monitoring are in order. By following these rules, management goals may be achieved at minimum cost.

SECTION 4

AIR POLLUTION CONTROL

AIR QUALITY REGULATIONS

Background

The Clean Air Act in its present form has its origin in the Clean Air Act Amendments of 1970. At that time Congress established the basic programs and philosophies under which we operate today. These programs can generally be broken down into three areas: 1) the attainment and maintenance of National Ambient Air Quality Standards (NAAQS); 2) limitations on the emissions of certain pollutants from stationary and mobile sources; and 3) a permit program for new sources. In conjunction with these programs, Congress established some statutory deadlines for such things as attainment of the NAAQS and emission levels for new automobiles.

The primary responsibility for implementing these and most other requirements of the Clean Air Act belongs to the individual states. The strategy and mechanism for accomplishing this is the State Implementation Plan (SIP), containing regulations and procedures developed by each state and approved by EPA for implementing the Act. Most states had approved SIP's in effect by 1972. State ambient air quality standards are shown in Table 52; stationary source emission standards for kraft and sulfite mills are listed in Table 53.

By 1976 it was evident that many deadlines had already been missed and that others were very likely to be missed. Congress recognized that something had to be done, and began an extensive revision of the Act, not only to relieve the deadlines, but also to deal with the many problems and deficiencies which had been identified during the six years since the last major revision.

National Ambient Air Quality Standards

To date, EPA has established NAAQS for six pollutants: sulfur dioxide (SO_2); total suspended particulates (TSP); carbon monoxide (CO); nitrogen oxides (NO_x); photochemical oxidants (O_x); and hydrocarbons (HC). Under the 1970 Act, all areas of the country were required to attain the NAAQS by July 1975. Many areas of the country (primarily urban) have not yet attained the standards. Recognizing this, the 1977 Amendments require that each state identify those areas which have not yet attained the standards and develop

TABLE 52. STATE AIR QUALITY STANDARDS

State	Sulfur dioxide Primary µg/cu m	Sulfur dioxide Secondary µg/cu m	Carbon monoxide Primary mg/cu m	Carbon monoxide Secondary mg/cu m	Nitrogen dioxide Annual arithmetic mean (AAM) µg/cu m	Photochemical oxidants µg/cu m max/1 hr
Alabama	80-AAM 365-24hr	1300-3hr	10-8 hr 40-1 hr		100	160
Alaska	80-Annual arithmetic mean (AAM) 365-24 hr 1300-3 hr		10-8 hr 40-1 hr		100	160
Arizona	80-AAM 365-24 hr 1300-3 hr		10-8 hr 40-1 hr		100	160
Arkansas	80-AAM 365-24 hr	1300-3 hr	10-8 hr 40-1 hr		100	160
California	80-AAM 131-24 hr		10-8 hr 46-1 hr 11-12 hr		100	200
Colorado	Category I II III AAM 2 10 15 24 hr max 5 50 100 3 hr max 25 300 700		9 ppm-8 hr 35 ppm-1 hr		0.05 ppm	0.08 ppm
Connecticut	80-AAM 365-24 hr	60-AAM 260-24 hr	10-8 hr 40-1 hr		100	160
Delaware	80-AAM 340-24 hr	60-AAM 260-24 hr 1300-3 hr	13.8-8 hr 40-1 hr		100	160

(continued)

TABLE 52. (Continued)

State	Sulfur dioxide Primary µg/cu m	Sulfur dioxide Secondary µg/cu m	Carbon monoxide Primary mg/cu m	Carbon monoxide Secondary mg/cu m	Nitrogen dioxide Annual arithmetic mean (AAM) µg/cu m	Photochemical oxidants µg/cu m max/1 hr
Florida	60-AAM 1300-3 hr		10-8 hr		100	160
Georgia	43-AAM 229-24 hr 715-1 hr		10-8 hr 40-1 hr		100-AAM 300-24 hr	98
Hawaii	20-AAM 80-24 hr		5-8 hr 10-1 hr		70-AAM 150-24 hr	100
Idaho	80-AAM 365-24 hr	1300-3 hr	10-8 hr 40-1 hr		100	160
Illinois	0.03 ppm-AAM 0.14 ppm-24 hr	0.50 ppm-3 hr	9 ppm-8 hr 35 ppm-1 hr		0.05 ppm-AAM	0.08 ppm
Indiana	80-AAM 365-24 hr	1300-3 hr	10-8 hr 40-1 hr		100	160
Iowa	80-AAM 365-24 hr	1300-3 hr	9 ppm-8 hr 35 ppm-1 hr		100	160
Kansas	None. A standing interpretation by the Kansas Attorney General has precluded the adoption of even Federal Standards on the basis they would allow deterioration.					
Kentucky	80-AAM 365-24 hr	1300-3 hr	10-8 hr 40-1 hr		100	160
Louisiana	80-AAM 365-24 hr	1300-3 hr	10-8 hr 40-1 hr		100	160

(continued)

TABLE 52. (Continued)

State	Sulfur dioxide Primary µg/cu m	Sulfur dioxide Secondary µg/cu m	Carbon monoxide Primary mg/cu m	Carbon monoxide Secondary mg/cu m	Nitrogen dioxide Annual arithmetic mean (AAM) µg/cu m	Photochemical oxidants µg/cu m max/1 hr
Maine	57-AAM 230-24 hr 1150-3 hr		10-8 hr 40-1 hr		100	160
Maryland	80-AAM 365-24 hr	1300-3 hr	10-8 hr 40-1 hr		100	160
Massachusetts	0.03 ppm	0.03 ppm	9 ppm		0.05 ppm	0.08 ppm
Michigan	80-AAM 365-24 hr	1300-3 hr	10-8 hr 40-1 hr		100	160
Minnesota	0.02 ppm-AAM 0.10 ppm-24 hr 0.25 ppm-3 hr		9 ppm-8 hr 30 ppm-1 hr		0.05 ppm	0.07 ppm
Mississippi	80-AAM 365-24 hr	60-AAM 260-24 hr 1300-3 hr	9 ppm-8 hr 35 ppm-1 hr		100	160
Missouri	53-AAM 365-24 hr 1300-3 hr		9 ppm-8 hr 35 ppm-1 hr		100	160
Montana	0.02 ppm-AAM 0.10 ppm-24 hr 0.25 ppm-1 hr					
Nebraska	80-AAM 365-24 hr	1300-3 hr	9 ppm-8 hr 35 ppm-1 hr		100	160

(continued)

TABLE 52. (Continued)

State	Sulfur dioxide Primary µg/cu m	Sulfur dioxide Secondary µg/cu m	Carbon monoxide Primary mg/cu m	Carbon monoxide Secondary mg/cu m	Nitrogen dioxide Annual arithmetic mean (AAM) µg/cu m	Photochemical oxidants µg/cu m max/1 hr
Nevada	60-AAM 260-24 hr 1300-3 hr		10,000 µg/m^3-8 hr <5000 ft m.s.l. 6670 µg/m^3-3 hr >5000 ft m.s.l. 40000 µg/m^3-1 hr all elevations		100	160
New Hampshire	60-AAM		9 ppm-8 hr 35 ppm-1 hr		100	0.08 ppm
New Jersey	80-AAM 365-24 hr	60-AAM 260-24 hr 1300-3 hr	10-8 hr 40-1 hr		100	160
New Mexico	0.02 ppm-AAM 0.10 ppm-24 hr		8.7 ppm-8 hr 13.1 ppm-1 hr		0.05 ppm-AAM 0.10 ppm-24 hr	0.06 ppm
New York	0.03 ppm-AAM 0.14 ppm-24 hr 0.05 ppm-3 hr		9 ppm-8 hr 35 ppm-1 hr		0.05 ppm	0.08 ppm
North Carolina	80-AAM		10-8 hr 40-1 hr		100	160
North Dakota	60-AAM 260-24 hr 715-1 hr		10-8 hr 40-1 hr		100-AAM 200-1 hr, 1% of 3 months	160
Ohio	60-AAM 260-24 hr		10-8 hr		100	119-1 hr 79-4 hr 40-24 hr

(Continued)

TABLE 52. (Continued)

State	Sulfur dioxide Primary µg/cu m	Sulfur dioxide Secondary µg/cu m	Carbon monoxide Primary mg/cu m	Carbon monoxide Secondary mg/cu m	Nitrogen dioxide Annual arithmetic mean (AAM) µg/cu m	Photochemical oxidants µg/cu m max/1 hr
Oklahoma	80-AAM 365-24 hr	1300-3 hr	10-8 hr 40-1 hr		100	160
Oregon	60-AAM 260-24 hr 1300-3 hr		10-8 hr 40-1 hr		100	160
Pennsylvania	80-AAM 365-24 hr	1300-3 hr	10-8 hr 40-1 hr		100	160
Rhode Island	80-AAM 365-24 hr	1300-3 hr	10-8 hr 40-1 hr		100	160
South Carolina	80-AAM 365-24 hr	1300-3 hr	10-8 hr 40-1 hr		100	160
South Dakota	80-AAM 365-24 hr		10-8 hr 40-1 hr		100-AAM 250-24 hr	160
Tennesee	80-AAM 365-24 hr	1300-3 hr	10-8 hr 40-1 hr		100	160
Texas	80-AAM 365-24 hr	1300-3 hr	10-8 hr 40-1 hr		100	160
Utah	80-AAM 365-24 hr	1300-3 hr	10-8 hr 40-1 hr		100	160

(Continued)

TABLE 52. (Continued)

State	Sulfur dioxide Primary μg/cu m	Sulfur dioxide Secondary μg/cu m	Carbon monoxide Primary mg/cu m	Carbon monoxide Secondary mg/cu m	Nitrogen dioxide Annual arithmetic mean (AAM) μg/cu m	Photochemical oxidants μg/cu m max/1 hr
Vermont	0.02 ppm-AAM 0.05 ppm-24 hr 0.10 ppm-1 hr		8.7 ppm-8 hr 35 ppm-1 hr			0.06 ppm
Virginia	80-AAM 365-24 hr	1300-3 hr	10-8 hr 40-1 hr		100	160
Washington	0.02 ppm-AAM 0.10 ppm-24 hr 0.40 ppm-1 hr		10-8 hr 40-1 hr		100	160
West Virginia	80-AAM 365-24 hr	1300-3 hr	10-8 hr 40-1 hr		100	160
Wisconsin	80-AAM 365-24 hr	1300-3 hr	10-8 hr 40-1 hr		100	160
Wyoming	60-AAM 260-24 hr 1300-3 hr		10-8 hr 40-1 hr		100	160
Washington, D.C.	75-AAM 285-24 hr 860-1 hr	57-AAM 225-24 hr 715-1 hr	10-8 hr 40-1 hr		100	160

(Continued)

TABLE 52. (Continued)

State	Nonmethane hydrocarbons µg/cu m max/3hr µg/cu m	Particulates Primary µg/cu m	Particulates Primary mg/cu m	Particulates Secondary mg/cu m	Others µg/cu m	Others max/1 hr
Alabama	160	75- Annual geometric mean (AGM) 260-24 hr		60-AGM 150-24 hr		
Alaska			60-AGM 150-24 hr		Reduced sulfur compounds 50µg/cu m-30 min	
Arizona	160		75-AGM 150-24 hr			
Arkansas	160	75-AGM 260-24 hr		60-AGM 150-24 hr		
California	160	60-AGM 100-24 hr		60-AGM 150-24 hr	Hydrogen sulfide 42µg/cu m-1 hr	
Colorado	0.24 ppm		Nondesignated areas 150-24 hr Designated areas 180-24 hr			
Connecticut	160	75-AGM 260-24 hr		60-AGM 150-24 hr		
Delaware		70-AGM 200-24 hr 500-1 hr		60-AGM 150-24 hr	Hydrogen sulfide 0.06 ppm-3 min average 0.03 ppm-1 hr average	

(continued)

TABLE 52. (Continued)

State	Nonmethane hydrocarbons µg/cu m max/3hr (6-9 a.m.)	Particulates Primary µg/cu m	 Secondary µg/m3	Others
Florida	160	60-AGM 150-24 hr		
Georgia	98	60-AGM 150-24 hr		
Hawaii	100	55-AGM 100-24 hr		
Idaho	160	75-AGM 260-24 hr	60-AGM 150-24 hr 1300-3 hr	Sulfuric acid mist 12µg/cu m-24 hr 30µg/cu m-1 hr Beryllium 0.01µg/cu m-24 hr
Illinois	0.24 ppm	75-AGM 260-24 hr	60-AGM 150-24 hr	
Indiana	160	75-AGM 260-24 hr	150-24 hr	
Iowa	160	75-AGM 260-24 hr	60-AGM 150-24 hr	
Kansas				
Kentucky	160	75-AGM 260-24 hr	60-AGM 150-24 hr	
Louisiana	160	75-AGM 260-24 hr	60-AGM 150-24 hr	

(Continued)

TABLE 52. (Continued)

State	Nonmethane hydrocarbons µg/cu m max/3hr (6-9 a.m.)	Particulates Primary µg/cu m	Particulates Secondary µg/m3	Others
Maine	160	50-AGM 100-24 hr		
Maryland	160	75-AGM 260-24 hr	150-24 hr	
Massachusetts		75-AGM	60-AGM	
Michigan	160	75-AGM 260-24 hr	60-AGM 150-24 hr	
Minnesota	0.24 ppm	75-AGM 260-24 hr	60-AGM 150-24 hr	Hydrogen sulfide 0.05 ppm-1/2 hr,twice per year 0.03 ppm-1/2 hr,twice every 5 days
Mississippi	160	75-AGM 260-24 hr	60-AGM 150-24 hr	
Missouri		60-AGM 150-24 hr		Sulfuric acid 10µg/cu m-24 hr 30µg/cu m-1 hr Hydrogen sulfide 70µg/cu m-1/2 hr,twice per year 42µg/cu m-1/2 hr,twice every 5 days
Montana		75-AGM 200-1% of days per year		Sulfuric acid 4µg/cu m-annual average 12µg/cu m-1% of days 30µg/cu m-1 hr, 1% of days Hydrogen sulfide 0.03 ppm-1/2 hr twice every 5 days 0.05 ppm-1/2 hr twice per year
Nebraska	160	75-AGM 260-24 hr	60-AGM 150-24 hr	

(continued)

TABLE 52. (Continued)

State	Nonmethane hydrocarbons μg/cu m max/3hr (6-9 a.m.)	Particulates Primary μg/cu m	Particulates Secondary μg/m3	Others	
Nevada	160	60-AGM 150-24 hr			
New Hampshire	160	60-AGM			
New Jersey	160	75-AGM 260-24 hr	60-AGM 150-24 hr		
New Mexico	0.19 ppm	60-AGM 150-24 hr		Hydrogen sulfide 0.003 ppm	
New York	0.24 ppm	75-AGM 250-24 hr			
North Carolina	160	60-AGM 150-24 hr			
North Dakota	160	60-AGM 150-24 hr		Hydrogen sulfide 45μg/cu m-1/2 hr, twice every 5 days 75μg/cu m-1/2 hr,twice per year	Sulfuric acid mist 4μg/cu m-AAM 12μg/cu m-24 hr,1% of time 30μg/cu m-1 hr,1% of time
Ohio	126	60-AGM 150-24 hr			

(continued)

TABLE 52. (Continued)

State	Nonmethane hydrocarbons µg/cu m max/3hr (6-9 a.m.)	Particulates Primary µg/cu m	 Secondary µg/m3	Others	
Oklahoma	160	75-AGM 260-24 hr	60-AGM 150-24 hr 1300-3 hr		
Oregon	160	60-AGM 150-24 hr	15% of samples >100µg/m3 in 1 month	Lead 3.0µg/cu m-1 month	Calcium oxide 20µg/cu m as TSP 0.35 gm/month as fallout
Pennsylvania	160	75-AGM 260-24 hr	60-AGM 150-24 hr 1300-3 hr		
Rhode Island	160	75-AGM 260-24 hr	60-AGM 150-24 hr 1300-3 hr		
South Carolina	160	75-AGM 250-24 hr	150-24 hr	Gaseous fluorides (HF) µg/sq cm 12 hr avg-3.7 24 hr avg-2.9 1 wk avg-1.6	1 month avg-0.8
South Dakota	160	60-AGM 150-24 hr			
Tennesee	160	75-AGM 260-24 hr	60-AGM 150-24 hr		
Texas	160	75-AGM 260-24 hr	60-AGM 150-24 hr 1300-3 hr		

(continued)

TABLE 52. (Continued)

State	Nonmethane hydrocarbons µg/cu m max/3hr (6-9 a.m.)	Particulates		Others	
		Primary µg/cu m	Secondary µg/m3		
Utah	160	75-AGM 260-24 hr	60-AGM 150-24 hr 1300-3 hr		
Vermont		45-AGM 125-24 hr			
Virginia	160	75-AGM 260-24 hr	60-AGM 150-24 hr 1300-3 hr		
Washington	160	60-AGM 150-24 hr			
West Virginia	160	75-AGM 260-24 hr	60-AGM 150-24 hr 1300-3 hr		
Wisconsin	160	75-AGM 260-24 hr	60-AGM 150-24 hr 1300-3 hr		
Wyoming	160	60-AGM 150-24 hr		Hydrogen sulfide 70µg/cu m-1/2 hr, twice per year 40µg/cu m-1/2 hr, twice every 5 days	Fluorides 80µg/cu m-24 hr
Washington, D.C.	160	75-AGM 160-24 hr	60-AGM 140-24 hr		

Source: Pollution Engineering (181)

TABLE 53. STATE STATIONARY SOURCE EMISSION STANDARDS

	Sources and pollutants (All measurements in kg/kkg of pulp, unless otherwise specified)							
	Kraft pulp mills					Sulfite pulp mills		
	Particulates					Particulates		
State	Recovery furnace	Smelt dissolving tank	Lime kiln	Total reduced sulfur (TRS)	sulfur oxides	100 kg/hr process weight	1,000,000 kg/hr process weight	sulfur compounds
Alabama	2.0	0.25	0.5	0.6	--	--	--	--
Arizona	--	--	--	--	--	--	--	4.5
Connecticut	--	--	--	--	--	--	--	4.5
Florida	3.0kg/3,000 kg black liquor feed	--	--	0.5 kg/3,000 kg black liquor feed	--	--	--	--
Idaho	2.0	0.25	0.5	1.0	--	--	--	--
Kentucky	--	--	--	0.25 (17.5 mg/l)	--	--	--	4.5
Louisiana	2.0	0.25	0.5	--	--	--	--	--
Maine	2.0	0.25	0.5	--	--	--	--	20
Mississippi	2.05	0.25	0.5	1.0	--	--	--	--
Montana	--	--	--	0.087 kg 1,000 kg black liquor (17.5 mg/l)	--	--	--	--
New Hampshire	2.0	0.25	0.5	--	--	0.25 kg/hr	31 kg/hr	--
New Mexico	2.0	--	--	0.05	--	--	--	--
North Carolina	1.5	0.3	0.25	--	--	--	--	--
North Dakota	--	--	--	--	--	--	--	4.5
Oklahoma	--	--	--	--	--	--	--	9.0

(continued)

TABLE 53 (Continued)

	Sources and Pollutants (All measurements in kg/kkg of pulp, unless otherwise specified)							
	Kraft pulp mills					Sulfite pulp mills		
	Particulates					Particulates		
State	Recovery furnace	Smelt dissolving tank	Lime kiln	Total reduced sulfur (TRS)	sulfur oxides	100 kg/hr process weight	1,000,000 kg/hr process weight	Sulfur compounds
Oregon	2.0	0.25	0.5	0.15 (10 mg/l)	200 mg/l	--	--	10
South Carolina	1.4	0.5	0.5	--	--	--	--	--
Tennesee	1.5	0.37	0.5	0.6	--	--	--	--
West Virginia	--	--	--	--	--	--	--	4.5
Wisconsin	--	--	0.25	--	--	--	--	--

Source: Battelle Columbus Laboratories. Multi-Media Pollution Assessment In Pulp, Paper and Other Wood Products Industry, 1976.

strategies that will ensure the attainment and maintenance of the primary standards by December 31, 1982, and the secondary standards as soon as possible. Congress has established strong sanctions for those areas for which SIP revisions are not approved by July 1979. Examples of these sanctions include not permitting new sources emitting pollutants which are especially hazardous to human health. Currently there are standards for sources of asbestos, mercury, beryllium, and vinyl chloride. Standards for benzene are impending. These standards apply to both existing and new sources, and new sources must obtain a permit prior to construction.

The fourth and final portion of the New Source Review program is the Prevention of Significant Deterioration, (PSD) which is likely to be the most restrictive requirement for new sources. The PSD section has two requirements: 1) that any new source install and operate the best available control technology (BACT) for reducing emissions; and 2) that all sources locating in any given area, together, not degrade air quality more than a specified increment. The increments, shown in Table 54, vary from very little degradation in Class I areas (currently National Parks and Wildernesses, National Memorial Parks and International Parks) to the greatest allowable degradation in Class III areas (there are currently no Class III areas). In no case will the air be allowed to degrade beyond the NAAQS. All major stationary sources which have the potential to emit over 250 tons per year of any pollutant will need a PSD permit before constructing. It should be noted that a source locating in or near a nonattainment area may have to satisfy both the offset and PSD provisions.

There is an increased emphasis on New Source Review, especially the PSD and offsets programs. It is evident that the air quality considerations in obtaining a permit to construct a new source or modify or expand an existing source have become more stringent. Industrial growth in or near nonattainment areas and near Class I areas will require the best control technologies. There will likely be some impact on the forest products industry because the resource (the forests), and hence the industrial development, is almost always in the vicinity of Class I areas. Air quality considerations will be an important, and perhaps a deciding, factor in future land management decisions.

One portion of the PSD program, the new national visibility goal, has the potential to impact the forest products industry, particularly with respect to prescribed burning. Congress has created a national goal to remedy existing and prevent future impairment of visibility in the mandatory Class I areas. The implementation of a strategy to accomplish this goal will be twofold: 1) a requirement that any major stationary source which may reasonably be anticipated to contribute to impairment of visibility, install the Best Available Retrofit Technology (BART) if it was built between 1962 and 1977; and 2) that the states develop a long-term strategy to accomplish the national goal. This portion of the Act may have an impact on such sources as pulp mills and hogged fuel boilers, as well as prescribed burning practices.

TABLE 54. PREVENTION OF SIGNIFICANT DETERIORATION AREA CLASSIFICATIONS AND ALLOWABLE INCREASES

Pollutant	g/cu m	National ambient air quality standards	
		primary	secondary
Class I[#]			
Particulate matter:			
Annual geometric mean	5	75	60
Twenty-four hour maximum	10	260	150
Sulfur dioxide:			
Annual arithmetic mean	2	80	-
Twenty-four hour maximum	5	365	-
Three-hour maximum	25	-	1300
Class II			
Particulate matter:			
Annual geometric mean	19	75	60
Twenty-four hour maximum	37	260	150
Sulfur dioxide:			
Annual arithmetic mean	20	80	-
Twenty-four hour maximum	91	365	-
Three-hour maximum	521	-	1300
Class III[†]			
Particulate matter:			
Annual geometric mean	37	75	60
Twenty-four hour maximum	75	260	150
Sulfur dioxide:			
Annual arithmetic mean	40	80	-
Twenty-four hour maximum	182	365	-
Three-hour maximum	700	-	1300

[*] Maximum allowable increase in micrograms per cu m (but not to exceed NAAQS).

[#] Initially included most national parks, national wilderness areas, national memorial parks, and international parks.

[†] Currently, there are no Class III areas.

NOTE: Presently, there are numerical increments only for total suspended particulates and sulfur dioxide. EPA is, however, required to study and promulgate numerical increments for other criteria pollutants by August 1979.

Source: (164)

Standards of Performance for Kraft Pulp Mills

On February 23, 1978, after receiving and reviewing comments for standards proposed on September 24, 1976, revised emission standards were established for the major emitting process units in new, modified, and reconstructed kraft pulp mills. New standards were published in the Federal Register Vol. 43, No. 37 FR on pages 7568-7598(186). These final rules require "best available control technology for new mills and establish limits for both particulate and total reduced sulfur (TRS) emissions. Process equipment with designated particulate limits include the recovery furnace, smelt tank, and lime kiln. Items with TRS limits are digester, evaporators, brownstock washers, black liquor oxidation system, condensate stripping systems, lime kiln, and smelt tanks.

Control strategies (BACT) include caustic scrubbing towers, adequate lime mud washing, "overdesign" of components such as brownstock washers, recovery furnaces, and evaporators. These new mill standards in many cases impose tighter restrictions than the maintenance of ambient air standards or present state (SIP) plans would require. The standards contained in the February 23, 1978 final rules are shown below:

Source	
	Particulates
recovery furnace	0.1 gram/cu meter (9/dscm) at 8 percent oxygen
dry black liquor solids - smelt tank	0.1 g/kg
lime kilns - gas-fired	0.15 g/dscm at 10 percent oxygen
oil-fired	0.30 g/dscm at 10 percent oxygen
	Total Reduced Sulfur
digester	5 ppm by vol. at 10% oxygen
multi effect evaporator	5 ppm by vol. at 10% oxygen
brownstock washer vents	5 ppm by vol. at 10% oxygen
condensate strippers	5 ppm by vol. at 10% oxygen
black liquor oxidation system	5 ppm by vol. at 10% oxygen
lime kiln	8 ppm by vol. at 10% oxygen
kraft recovery furnace	5 ppm by vol. at 8% oxygen
kraft-NSSC recovery furnace	25 ppm by vol. at 8% oxygen
black liquor solids - smelt tank vent	0.0084 g/kg

Compliance and Enforcement

The 1977 Amendments substantially strengthened the enforcement features of the Act by including procedures for levying civil and criminal penalties of up to $25,000 per day of violation and imprisonment for up to one year, or both, for violation of Clean Air Act requirements.

Congress has also established a requirement for levying a non-compliance penalty against sources which are not complying with applicable emission limitations, compliance schedules, or other requirements of the Act or SIP. The penalty will be equivalent to the cost of installing and operating the necessary control equipment for compliance, and will be no less than the economic value which the delay in compliance might have for the owner of the source. In general, there will no longer be any economic justification for not installing control equipment, because the cost for complying will be the same as the penalties levied.

Congress has now required that any federally-owned source or federal activity which results in emissions comply with both the substantive and procedural requirements of the state and local agencies. This is a change in the concept of federal supremacy. It has an immediate impact on the forest products industry. Now, all activities on federal lands, such as those managed by the U.S. Forest Service or Bureau of Land Management, must comply with state and local requirements.

Summary

The Clean Air Act, as amended in August 1977, is a strong vehicle to attain and maintain clean air in this nation. The emphasis during the next few years will be on cleaning up those areas not yet attaining standards and maintaining or improving air quality in areas which are cleaner than the national standards. The responsibility for implementing the requirements of the Act rests primarily with the state and local agencies and the strategies they choose will reflect both federal requirements as well as local conditions. It appears likely that many of the requirements and strategies will impact the wood products industry.

POLLUTANT CHARACTERIZATION AND IMPACT

Introduction

Atmospheric pollutants in the wood products industry include particulates, sulfur dioxide (SO_2), total reduced sulfur compounds (TRS), chlorine compounds, water vapor, and salt. The environmental impact of these pollutants is largely dependent on local conditions including: point of emission; local terrain; and prevalent atmospheric conditions. For example, mills located in valleys with poor dispersion characteristics may create a greater impact with a given emission mass loading.

The following paragraphs address the character and potential environmental impacts associated with each pollutant.

Particulates

Particulates emitted from kraft pulping processes range from up to 30 micrometers (um) in diameter (e.g. wood char from hogged fuel boilers) to less than 1 um (e.g. sodium sulfate, sodium carbonate, sodium chloride).

The health concern associated with particulates is their ability to penetrate and cause direct tissue damage to the alveoli of the human lungs. Another concern is the ability to be taken up by the phagocytes and transported by the blood to the lymph stream.(153) The ultimate effects of these phenomena on human health are not well documented.

There is also a health concern over sodium sulfate and sodium carbonate aerosols emitted by recovery boilers. This mixture is slightly alkaline and its exact effect on health is not well understood.

Fine particles emitted from the lime kiln include alkaline calcium oxide, and inert calcium carbonate. The tolerance level for continuous exposure to calcium oxide is given by the American Council of Government Industrial Hygienists (ACGIH), as 5,000 ug/cu m. Studies have shown ambient concentrations in the vicinity of pulp mills to be well below this level.

Particulates can have an impact when they settle out of the atmosphere by gravity. Most fallout occurs within two miles of a mill.(154) Larger particles can cause soiling, while chemical salts can cause corrosion in the affected area.

Fine particle emissions also tend to create an atmospheric haze in the vicinity of the discharge. This, coupled with water vapor emissions, can create a fog-like plume through condensation of the water vapor on the particulates. This plume can persist for several miles, especially in coastal regions where it is enhanced by sodium chloride.

Wood preserving with creosote solutions and oilborne preservatives can result in atmospheric emissions exceeding opacities and concentrations permitted under current air pollution regulations.

Sulfur Dioxide

Sulfur dioxide (SO_2) is emitted primarily from kraft pulp mills. Vegetation can be damaged by continuous exposure of SO_2 in concentrations on the order of 300 ug/l or higher.(155) Typically the SO_2 concentration in kraft mill stacks is 50-200 mg/l. There is some evidence to indicate that at low levels SO_2 can be beneficial to plants. Thus the impact, if any, would depend largely on local conditions including dispersion.

SO_2 can also be a strong irritant perceptable by odor and taste. The maximum concentration allowed by OSHA is 4 mg/l, with 13 ug/l for a maximum time weighted average.

Total Reduced Sulfur Compounds (TRS)

The major environmental impact of reduced sulfur compounds is their noxious odor and extremely low detectability. The compounds of concern and their detectability by the human nose are shown below.(155)

Reduced sulfur compound	Lower detectable limit (ppb)
Hydrogen sulfide	8-20
Methyl mercaptan	2.4
Dimethyl sulfide	1.2
Dimethyl disulfide	15.5

Chlorine Compounds

The chlorine compounds used in pulp bleaching and wood preserving are extremely corrosive to metals and/or hazardous to human health.

AIR EMISSION SOURCES IN THE PULP, PAPER, AND PAPERBOARD INDUSTRY

The pulp and paper segment of the wood products industry is the most significant source of air emissions. The emissions of this segment are best discussed by breaking down the division into four subcategories, three of which make up the bulk of the discharge.

Kraft Pulping

The kraft (sulfate) subcategory is the major offender, with emissions of various sulfur compounds and particulates. Within this process the digester - blow tank portion, where the wood is cooked, is a main source of gaseous emissions. The reduced sulfur compounds of dimethyl sulfide and dimethyl disulfide are the most important of those. Very little gaseous emission occurs when the cooked wood (pulp) is washed in the stock washing process.

Black liquor oxidation, a process more widely applied in the kraft process, has as a main purpose of chemical recovery. It also facilitates the removal of odorous sulfur compounds by oxidation. However, improper operation can increase the discharge of dimethyl disulfide and produce an extremely noxious odor by the release of methyl mercaptan.

Two main evaporation systems are wood in the kraft process to bring the black liquor to a concentration at which it can efficiently be burned: multiple-effect evaporators and direct contact evaporators. When used in conjunction with black liquor oxidation, emissions from the evaporators can be further reduced. Compounds typically emitted from multiple-effect evaporators are hydrogen sulfide and mercaptan. Direct contact evaporators are bigger offenders. In addition to greater discharges of hydrogen sulfide and mercaptan, particulates are released in significant quantities by direct contact evaporators.

The kraft process uses a recovery boiler in order to recover cooking chemicals from the spent cooking liquor, and as a means of steam generation. The extent of emissions from the recovery boiler hinges upon its manner of operation. Hydrogen sulfide, sulfur dioxide and particulates are the major pollutants discharged. Furnace flue gases can be discharged to the evaporators for further heat recovery, or can be incinerated (e.g. in the lime kiln) to further reduce emissions.

The smelt dissolving tank produces a low level of emissions, but the vigorous reaction that occurs there can entrain particulates in the gases (which include reduced sulfur compounds) that are discharged. A vigorous reaction can also occur in the slaker-causticizer, where particulates are also carried out in the steam that is generated in lime slaking.

Particulates are the primary emission of concern from the lime kiln, where calcium oxide is recovered after slaking. Reduced sulfur compounds are also emitted.

Table 55 lists air emissions which are typical of kraft pulping with and without black liquor oxidation.

Sulfite Pulping

Within the sulfite subcategory, there are four main chemicals, upon which the cooking process is based: calcium, magnesium, sodium, and ammonia. Recovery of the spent cooking liquors ranges from good with magnesium to poor with calcium. The following discussion of the sulfite process is directed toward the magnesium based sulfite process.

Absorption towers are used to produce sulfite solutions by absorbing sulfur dioxide gas in alkaline carbonate solutions. The primary emission from these towers is sulfur dioxide gas which is not absorbed.

The digester - blow tank segment of the process can be a significant source of sulfur dioxide discharges. Depending on the greater discharge method, the sulfur dioxide released varies significantly.

Neutral Sulfite Semichemical (NSSC)

Wood chips are cooked in a mild chemical solution in the NSSC process; the resulting pulp is then handled as in other processes. There are fewer air emissions from the NSSC process. Methyl mercaptan and disulfite do not form during digestion and hydrogen sulfide is reduced because the sulfide is absent.

TABLE 55. TYPICAL KRAFT PULPING AIR EMISSIONS

Pollutant operation	SH_2S (kg/kkg)	Reduced sulfur compounds (RS) Methyl mercaptan (kg/kkg)	Dimethyl sulfide (kg/kkg)	Dimethyl disulfide (kg/kkg)	Total RS (TRS) (kg/kkg)	SO_2 (kg/kkg)	Particulates (kg/kkg)
Without black liquor oxidation							
Digester blow tank	0.01-0.06	0.01-0.20	0.20-1.3	0.10-0.75	0.24-5.43 (1.8 avg)	TR-0.01	-
Stock washer	0.01-0.06	0.05-0.13	TR-0.01	TR-0.01	#	TR-0.01	
Multiple effect evaporator	0.05-1.5	0.05-0.75	0.03-0.04	TR-0.01	0.13-2.3	TR-0.01	
Direct contact evaporator with recovery furnace	2.5-15.0	0.25-1.25	0.05-0.15	0.05-0.70	2.9-16.8	1.0-4.0	1.1-37.6
Smelt tank	0-0.09	0-1.0	0-0.90	0-0.19	0-2.4	0-1.05	0.03-1.19
Lime kiln	0-2.0	0.0-0.18	0-0.23	0-0.11	0-3.81	0-1.18	0.8
Total - range	2.5-18.7	0.37-3.0	0.28-2.2	0.15-1.27	4.9-27.1	1.0-5.8	1.9-39.6
average	10.6	1.7	1.2	0.7	.16.0	3.4	20.8

(continued)

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*Operations not listed in the "with black liquor oxidation" section have the same discharges as indicated in the "without black liquor oxidation" section.

#Total not reported.

Source: Battelle Columbus Laboratories. Multi-Media Pollution Assessment In Pulp, Paper and Other Wood Products Industry, 1976

TABLE 55. (Continued)

Pollutant operation	SH_2S (kg/kkg)	Reduced sulfur compounds (RS) Methyl mercaptan (kg/kkg)	Dimethyl sulfide (kg/kkg)	Dimethyl disulfide (kg/kkg)	Total RS (TRS) (kg/kkg)	SO_2 (kg/kkg)	Particulates (kg/kkg)
With black liquor oxidation*							
Black liquor oxidizer	TR-0.01	0.03-0.05	0.01-0.04	0.03-0.08	0.002-0.5 (0.17 avg)	TR-0.01	-
Multiple effect evaporator	0-3.0	0.001-0.15	0.0001-0.08	0.0002-0.08	0.0002-0.75	0.01	-
Direct contact evaporator with recovery furnace	0.5-1.0	0.30-0.13	0.01-0.05	0.01-0.10	0.6-1.4	1.0-4.0	1.1-37.6
Total: range average	0.52-4.7 2.6	0.17-1.3 0.7	0.25-2.2 1.2	0.17-1.9 1.0	0.92-14.1 6.3	1.1-5.8 3.5	3.9-39.6 20.8

*Operations not listed in the "with black liquor oxidation" section have the same discharges as indicated in the "without black liquor oxidation" section.

#Total not reported.

Source: Battelle Columbus Laboratories. Multi-Media Pollution Assessment In Pulp, Paper and Other Wood Products Industry, 1976

Both the absorption tower and digester - blow tank segments of the process have emissions very similar to their counterparts in the sulfite category. A variety of gases are released in the discharge of the digesters.

Evaporator emissions are negligible, consisting of a large volume of condensate and a small volume of vent gas. The fluidized bed reactor - wet scrubber process recovers sodium sulfate and sodium carbonate compounds. This process emits a large volume of vent gas containing relatively small amounts of particulates, sulfur dioxide and hydrogen sulfide.

Typical air emissions from NSSC and from sulfite processes are shown in Table 56.

TABLE 56. EMISSION RANGES FOR SULFITE AND NSSC PROCESSES

Pollutant operation	H_2S (kg/kkg of product)	SO_2 (kg/kkg of product)	Miscellaneous
Sulfite paper process			
Adsorption tower		7.5 - 10	
Digester		5 - 75	Steam
Pulp washer		2	
Evaporator		2.5 - 5.0	
Recovery boiler		Small amount	
NSSC paper process			
Adsorption tower	Slightly less than sulfite above		
Digester			Large volume of condensate, small volume at vent gas
Evaporator			
Fluidized bed Reactor - scrubber	10	10	

Source: Batelle Columbus Laboratories. Multi-media Pollution Assessment In Pulp, Paper and Other Wood Products Industry, 1976.

Mechanical Pulping

When compared to the chemical pulping processes, mechanical process produce no significant air emissions.

Power Boilers

Power boilers are essential to the manufacture of pulp, paper, and paperboard due to the large quantities of steam required by the process. Fuel burned by the boilers are coal, gas, oil, or bark, in any combination or separately (except for bark). Significant sulfur dioxide is emitted from coal or oil fired boilers, with particulates emitted by all boilers.

Wood Waste Combustion

Wood waste, once just a nuisance in most forest products industry operations, is now considered a valuable energy resource. As a natural byproduct of the industry's resource utilization, wood waste is an attractive alternative to more expensive fossil fuels. The industry has for many years used wood-fired boilers to produce process steam and electricity, while at the same time solving a large-scale wood waste disposal problem. In the Pacific Northwest, for example, there are approximately 1,000 industrial wood-fired boilers in operation. Junge reports that annual use of wood fuels in Oregon alone is equivalent to more than 19 million barrels of oil.(156)

The combination of wood residues in hogged fuel boilers creates a particulate emission composed of fly ash, or the unburned remains of wood or bark fuel, including sand or dirt picked up during the logging operation. If not controlled, this fly ash can result in visible stack emissions. Most states regulate both the particulate emission rate and the visible emissions, or opacity, of stack effluents. Although the regulations vary from state to state, most requirements can be met with air pollution control devices presently available. The particles emitted from hogged fuel boilers are relatively large, and thus relatively easy to collect.

Wastewater Sludge Combustion

Due to rising landfill costs and scarcity of suitable disposal sites it is becoming more common for mills to burn wastewater treatment plant sludge to recover the heat value and reduce the volume of solids to landfill. Typically a low ash sludge dewatered to a solids content of ±30 percent will burn without need for auxiliary fuel except during startup.(157) This would apply to primary and biological sludges, however, the higher inorganic content of sludge from chemical clarification make the latter less suitable for incineration. In any case a higher solids content would improve the heat value.

In order to attain the required solids concentration conventional dewatering methods such as the vacuum filter and horizontal belt filter must be followed by the more expensive and sophisticated filter press. Additional research is needed on an industry wide basis to determine the feasibility and implications of this approach with respect to: 1) effect on combustion/boiler system 2) existing burning capacity; 3) air emissions; and 4) economics.

EMISSIONS FROM OTHER WOOD PRODUCTS INDUSTRIES

Six major categories make up the remainder of the wood products industry: converted paper products; veneer/plywood; particleboard; millwork, structural members, fabricated wood products; and gum and wood chemicals and wood preserving.

Within the gum and wood chemicals subcategory, the wood rosin, turpentine, and pine oil category obtains terpene as a distillation byproduct. Terpene is burned in a boiler, which may emit combustion byproducts. Residue from the distillation of wood chips to recover essential oils is burned to recover the heat value. Some pollutants may be discharged from this process.

The only significant air emissions occur within the veneer/plywood, particleboard, and wood preserving segments of other wood products industry. Major emissions from the veneer/plywood, particleboard, and gum and wood chemicals subcategories are summarized in Table 57. One of the areas of greatest concern is veneer dryer emissions, as discussed below. A discussion of air emissions from the wood preserving industry follows that for veneer dryers.

No significant air emissions are discharged from the converted paper products category. There are also no significant air emissions from the millwork, structural members, and fabricated wood products subcategory.

Veneer Dryer Emissions

At the point of discharge from the exhaust stack, veneer dryer emissions consist of hot air, a small amount of wood fiber, water vapor and gaseous organic compounds that have been distilled from the wood veneer. The character and quantity of these steam-distilled organics are related to the wood species, the drying temperature, the humidity in the dryer, and the type of dryer.

In the early 1970's, state and regional air pollution control agencies formed a committee to establish a source test procedure for the determination of particulate emissions from veneer dryers. This test procedure addressed only the distilled organic gases that condensed at standard temperature (70°F); these were classified as particulates. Subsequent tests on local veneer dryers demonstrated that, for the most part, veneer dryers met current emission standards for existing sources. Control of dryer emissions was subsequently directed toward reducing the visible blue-haze emissions to 10 to 20-percent opacity. The noncondensible fraction of these organic emissions was not addressed until recent studies showed that photochemical oxidants were exceeding air quality alert levels in many parts of the country.

Photochemical oxidants are formed by chemical reactions in the atmosphere between reactive hydrocarbons and oxides of nitrogen in the presence

TABLE 57. MAJOR EMISSIONS FROM OTHER WOOD PRODUCTS SUBCATEGORIES

Subcategory/pollutant operation	Hydrocarbons	Particulates	Miscellaneous
Veneer/plywood			
Veneer dryer	50 to 100 lb/1,000 cu ft product		Blue plume saturated w/water vapor emitted
Incineration		10 lb/ton wood waste burned	130 lb CO/ton wood waste burned
Panel press operation	Phenolic resins discharged		
Sander		33 to 99 tons/10^6 sq ft plywood	
Particleboard			
Drying, sanding, pressing	Some discharged	8 to 25 lb/1,000 sq ft	
Incinerator		2 to 8 lb/1,000 sq ft particleboard	
Material handling operation			Highly variable emissions
Gum and wood chemicals			
Char production			Products of volatile oxidation

Source: Batelle Columbus Laboratories. Multi-media Pollution Assessment In Pulp, Paper, and Other Wood Products Industry, 1976.

of sunlight. EPA's strategy for achieving air quality standards for photochemical oxidants is to reduce emissions of hydrocarbon precursors. According to the EPA strategy, reducing hydrocarbon emissions from industry sources and motor vehicles would limit the amount of hydrocarbons available for sunlight-induced reaction and thus reduce photochemical oxidants. However, a recent report by Radian Corporation (158) studied the relationship between anthropogenic hydrocarbon emissions and ambient ozone levels using data from five American cities. The results showed that in three cities (Cincinnati, Philadelphia, and San Francisco) reductions in hydrocarbon emissions were accompanied by increases in ozone levels. In the fourth city (Houston), reductions in hydrocarbon emissions were accompanied by no clear change in ozone levels. In the fifth city (San Diego), emissions of hydrocarbons and ambient ozone levels remained virtually unchanged.

Condensible hydrocarbon emissions in the wood products industry are produced almost exclusively by veneer dryers. The condensible organics average about 70 percent of the total organic emissions from veneer dryers. The lifetime of these primary particles is short; in the absence of chemical reactions, a major portion of the condensed organics quickly revaporizes. The fate of those veneer dryer emissions which remain permanently in particle form can be predicted, provided one knows the particle size distributions and the chemical reactivity of the particles. If the chemical reactivity is low, these particles can be treated as any other stable group of particles with a similar size distribution. Thus, their lifetime in the local atmosphere can be estimated and models can be used to determine their impact on total suspended particulate (TSP).

The volatile component and the revaporized primary particles have two possible fates. Some of them may follow the hydrocarbon-to-oxidant pathway, possibly increasing the oxidant concentration in the area; the rest may follow the hydrocarbon-to-particle pathway, producing secondary particles. These secondary particles are quite distinct from the primary particles evident in the veneer dryer plumes. They are produced slowly, over a period of hours to days, and over an entire airshed. They become visible and are associated with the characteristic aerosol haze in rural areas like the Smokey Mountains in North Carolina or the Blue Ridge Mountains of Virginia. They can also contribute to urban smog.

Of the possible fates, Cronn and Campbell (159) believe that the majority of veneer dryer emissions take the route to secondary particle formation. Campbell, working with related hydrocarbons, observed that more than 80 percent of the hydrocarbons were rapidly converted to secondary particles, leaving less than 20 percent available for oxidant production. Similar conclusions have been reached by Gay and Arnts.(160)

On the other hand, in a statement published in the Federal Register on July 8, 1977, titled, "Recommended Policy on Control of Volatile Organic Compounds," the EPA stated that in the analysis of available data, very few volatile organic compounds are of such low photochemical reactivity that they can be ignored in oxidant control programs. Reactivity scales are measures of the rate at which hydrocarbon compounds react in the ambient air. EPA has classified terpenoids as highly reactive. The classification specifically assumes that all of the hydrocarbon is consumed in producing ozone. There is evidence that this is not true for wood-related hydrocarbons, which actually consume oxidant by reacting directly with ozone in the atmosphere. In fact, Gay and Arnts were able to account for only a few percent of the heavy, wood-related hydrocarbons which they reacted with nitrogen oxides; the bulk of the hydrocarbons was apparently being converted into particles.

At the request of the American Plywood Association, the team at Washington State University submitted a research proposal (159) with the following goals and objectives:

Project A:	Physically and chemically characterize the gaseous and particulate emissions from four to five veneer dryers of varying types and/or feedstocks.
Project B:	Determine the lifetime of the primary particle plume above veneer dryers, and the fraction of it which is persistent.
Project C:	Determine the yields of particles and oxidant from a typical veneer dryer, during a 2-day period of residence of the emissions in the atmosphere.

In their summary, they felt the following data was needed to determine the significance of wood product hydrocarbon emissions in local air pollution.

1. Information is needed on the actual partition of wood hydrocarbons between particle and gas phases at the stack, using veneer dryers as a source. Older studies of this subject, with categorizations into condensible and non-condensible fractions, are probably misleading. The size distribution and chemical stability of the persistent primary particles need to be determined.

2. The ratio of gaseous hydrocarbons going respectively to oxidant formation and secondary particle formation is urgently needed. It is expected that almost all wood product hydrocarbon gases will end up as secondary particles. If this proves to be true, there may be differences of factors of several-fold in the air pollution significance of a given rate of veneer dryer emissions.

Wood Preserving Emissions

When creosote and oilborne (pentachlorophenol) preservative solutions are heated, lower boiling point organics vaporize to produce dense white emissions. When tram cars are pulled from the retort, the white plume from the freshly treated wood may exceed 60 percent opacity beyond the opaque water vapor breakoff point and continues to exceed 40 percent up to 20 minutes. Additional emissions are released from the open end of the retort during a few minutes required to remove a tram of treated wood and recharge the retort with a tram of virgin material. During that brief period, emissions occur which exceed 60 percent opacity beyond the opaque steam plume.(161)

High atmospheric particulate concentrations occur in the vacuum exhaust as well as in the exhaust during steam cleaning. Source tests at one mill revealed 2.2 g/cu m (0.95 grain/scf), or 1.6 kg/hr (3.6 lb/hr) in 12.5cu m/min (440 scfm) of gas from a vacuum pump venting one retort at the start of the vacuum cycle. Steam cleaning released 44 g/m^3 (19 grains/scf) or 34 kg/hr (75 lb/hr) in 13cu m/min (460 scfm).(162) Some mills may exceed these grain loadings.

Ammonical copper arsenite (ACA) wood preserving plants, in contrast to creosote plants, present a nuisance odor abatement problem and not an opacity problem. Ammonia vapors are released during vacuum cycles, gas purging of the retort, and from treated wood just after its removal from the retort. Other potential ammonia sources are the barometric hot well, and preservative mixing and storage tanks.

Wood treatment with fire retardants and other water soluble preservatives presents no known air pollution regulatory problems.

Pentachlorophenol and many components of water soluble preservatives are acutely toxic. They are chosen for their biocidal properties. Entirely aside from air pollution-oriented regulations, atmospheric releases of these chemicals must be avoided to prevent inhalation by employees. Non-automated mixing is a particularly likely source of toxic particulates release. Bourgeois has reported visible deposition of toxic inorganics on floors and soil at one mill.(163)

EMISSION CONTROL TECHNOLOGIES

A number of technologies are currently used to reduce air pollutant emissions. A brief description of the more common technologies and their applications is presented in the following paragraphs.

Scrubbers

Scrubbers are air pollution control units in which liquids are used to remove aerosols from gas streams. Particles can be wetted by contact with a liquid droplet; wet or dry particles may contact a collecting surface from which they are subsequently rinsed. The liquid can be fresh water, a specifically prepared solution, or a process stream. Scrubbers can be effective in removing particulates, reduced sulfur compounds, and organic non-sulfur compounds. Four main scrubber types, with variations, are in use in the pulp and paper industry. These four types, venturi, cyclone, impingement and packed tower are discussed in the following paragraphs.

Venturi scrubbers consist of a convergent section (throat) and divergent section. As gas enters the throat it increases in velocity. Liquid contacts the gas just before the divergent section, and the liquid becomes fine droplets. The droplets contact gas particulates which are entrapped, and the gas then exits the unit while the particles are contained, separated by centrifugal force (often by means of a cyclone separator).

Gas enters a cyclone scrubber at its base and spirals upward while liquid is sprayed on the gas as it passes through the unit. Gas particulates are trapped in the droplets which strike against the unit walls and fall to the bottom, where they are removed. Meanwhile the gas exits the top.

Impingement scrubbers consist of two main operations. Gas enters the bottom of the unit and is sprayed with liquid to remove large particles. Gas then passes through a series of perforated baffles where the scrubbing liquid is atomized and particulates are entrapped in the droplets. The droplets then fall to the bottom of the unit while the gas exits the top.

Packed tower scrubbers are cylindrical units packed with inert material of various shapes. Liquid scrubbing media enter from the top of the tower, while the gas to be scrubbed enters from the bottom. The inert packing material creates a large volume of surface contact area for the gas and scrubbing medium. Depending on the situation, either a gas stripper (such as air or steam) or liquid scrubber (such as white liquor) may serve as the medium. Pollutants removed by various media are shown in Table 58.

TABLE 58. POLLUTANTS REMOVED BY VARIOUS SCRUBBING AND STRIPPING MEDIA

Solution	Particulate	TRS	H_2S	SO_x	Cl_2	ClO_2
Alkaline solution	X	X	X	X	X	
Alkaline suspension of activated carbon	X	X	X			
Water & $FeCl_3$ solution	X		X			
Thin black liquor solution	X					
Steam/air stripping (in packed towers)		X				
H_2O_2						X
Cold water	X			X		

Source: (164)

Electrostatic Precipitators (ESP)

An ESP consists of discharging and charging electrodes, and a high-voltage power rectifier, which converts AC power to high-voltage direct current. The discharge electrodes negatively charge the particulates in the gas stream which then are attracted to the positively charged collecting electrodes. The collecting electrodes are grounded causing collected particles to lose their negative charge, and fall to a collecting surface. A rapping mechanism is used to dislodge the particles from the collecting surfaces. ESP can be effective in the removal of particulates and reduced sulfur compounds.

Cyclone Separators

Cyclone separators are inertial, or centrifugal, separators which separate particulate matter from a gas stream by transforming the inlet stream velocity into a double vortex contained within the cyclone. In the double vortex, the entering gas spirals downward at the outside and upward at the inside of the cyclone outlet. Because of their inertia, particulates tend to move toward the outside wall, from which they go to a collector.

Fabric Filtration

Gas enters the fabric filtration unit (baghouse) and particulates are captured and retained on the cloth. Once a mat of particles is accumulated, the particles themselves are also responsible for capturing additional particles. Cleaning is done regularly.

Mist Pads

Mist elimination pads consist of fine wire mesh screens, about 1 foot thick. Droplets condense from the gas and the pads are backwashed by water sprays. Most pads can be effective in the removal of particulates and reduced sulfur compounds.

Chlorination

Chlorination of various condensate stream is effective in the reduction of odor caused by reduced sulfur compounds, as these compounds have a high chlorine demand. Chlorination is expensive unless a chlorine source is readily available.

Black Liquor Oxidation

Black liquor oxidation is a kraft mill process operation carried out in order to recover process chemicals, as well as to control air pollution. Both strong and weak black liquors are oxidized in packed towers, bubble tray towers, and agitated or unagitated sparging units. Either air or molecular oxygen is used. This process controls the emission of reduced sulfur compounds, especially H_2S.

Incineration

Incineration of waste gases is often accomplished in the lime kiln, and can be done in the recovery furnace or power boiler. It is effective in the removal of reduced sulfur compounds and organic non-sulfur compounds.

Condensation

Condensation of gases from digesters and evaporators, allows heat recovery and the reduction of gaseous emissions of reduced sulfur compounds and organic non-sulfur compounds.

A summary of the applicable technologies and pollutants removed in certain areas of kraft and sulfite mills respectively is shown in Tables 59 and 60. Removal efficiencies, costs, applications and advantages, and disadvantages of various air pollution control technologies are summarized in Table 61.

Wood Preserving Air Emission Controls

The high particulate concentration from the vacuum and steam cleaning exhausts require a 96 percent removal to comply with emissions relations.(161) A venturi scrubber of this efficiency (capable of collecting suspended particulate in the micrometer size range) would need a 0.089 kg/sq cm (35 inches water) pressure drop across its throat.(162) Such a scrubber may have prohibitively high capital and operating costs.

An attractive alternative control technique to reduce particulate emissions during vacuum cycle and steam cleaning is incineration in an afterburner. Gas stream volumes may run 8.5 to 34 cu m/min (300 to 1200 scfm). To condense live steam and rough out the contaminant load, a surface condenser and knockout tank precede the afterburner.

To prevent fouling, naphthalene crystals must be removed periodically from the condenser. Duct velocities must exceed flame front velocities to avoid flashback from incinerators. Exit temperatures of 815°C and retention times exceeding 0.3 sec are adequate. 99 percent efficiencies are achieved, with exit grain loadings of 0.09 g/cu m (0.04 grain/scf). Afterburner waste heat should be recovered.(162)

IN-PLANT PROCESS CONTROLS TO REDUCE EMISSIONS

Pulp, Paper, and Paperboard Industry

Significant internal controls can be utilized by the pulp, paper, and paperboard industry to minimize air emissions. Some of these controls complement other processes in that control of emissions in one location may ease the problems in others.

TABLE 59. KRAFT MILL APPLICABLE AIR POLLUTION CONTROLS AND POLLUTANTS REMOVED

Source-pollutant	Digester			Evaporator			Washer		Recovery Boiler						Lime burning-dust handling				Smelt dissolving tank		Power boiler				Bleach plant		
Controls used	TRS	especially H_2S	organic non-S compounds	TRS	especially H_2S	organic non-S compounds	TRS	organic non-S compounds	TRS	especially H_2S	organic non-S compounds	particulates	NO_x	SO_x	TRS	particulates	NO_x	SO_x	TRS	particulates	Organic non-S compounds	particulates	NO_x	SO_x	SO_x	Cl_x	ClO_2
Scrubbers (unspecified)				X											X	X	X	X	X						X	X	X
Venturi												X		X		X			X	X		X					
Cyclone																X			X	X							
Impingement																X						X					
Absorption/packed tower	X	X		X	X				X	X		X							X	X					X		
Electrostatic precipitator (ESP)									X			X				X						X					
Cyclone separator																X						X					
Fabric filter (baghouse)																						x					
Mist pads																				X							
Chlorination	X			X																							
Combinations																											
ESP & scrubber											X								X	X							
Cyclone sep. & scrubber																X											
Mist pads & scrubber																			X	X							
Black liquor oxidation (BLO)				X	X																						
Incineration in lime kiln/rec. or power boiler	X		X	X		X	X	X																			
Condensation	X		X																								
Internal controls											X		X									X	X	X			
Venturi & packed tower									X			X	X														

Source: U.S. Environmental Protection Agency (164)

TABLE 60. SULFITE MILL APPLICABLE AIR POLLUTION CONTROLS AND POLLUTANTS REMOVED

Source pollutant / Controls used	Digester	Evaporator	Washer	Recovery boiler				Power boilers			
	SO_x	SO_x	SO_x	SO_x	NO_x	H_2S	Particulates	SO_x	NO_x	Particulates	Organic non-S compounds
Scrubbers (unspecified)	X	X	X	X							
Venturi				X						X	
Absorption/packed tower	X	X					X				
Electrostatic precipitator (ESP)							X				
Cyclone separator							X			X	
Fabric filter										X	
ESP & scribber							X				
Internal controls	X	X			X			X	X		X

Source: U.S. Environmental Protection Agency (164)

TABLE 61. SUMMARY OF AIR POLLUTION CONTROL TECHNOLOGIES

Device	%[*] Efficiency (pollutants)	Cost[#] Capital	Cost[#] O&M (date)	Advantages/disadvantages	Usage[†]
Venturi scrubber	95-99+	$22-27/TPD $0.6-4/CFM	$6-10/TPD/Yr (10/76)	Required less ground space than most particulate controllers, has few internal parts to maintain. Cost of op'n=50-60%>ESP	Used in many lime kilns; limited use in recovery boilers & smelt dissolving tanks
Cyclone scrubber	65-96	0.5-2.1/CFM	-	-	Normally used in conjunction with mist pads in lime kiln
Impingement scrubber	92-97	$29-32/TPD	$3-6/TPD/Yr	Efficient on coarse particulates (>10μ)	Used in a few lime kilns, & in wood burning power boilers
Absorption/ packed tower	80-909TRS) 85-98(particulates) 98-99(H_2S) 90-97(SO_2)	$2-8/CFM plus installation	-	Subject to plugging and channeling	Widespread usage not common

(continued)

TABLE 61. (Continued)

Device	%* Efficiency (pollutants)	Cost#		Advantages/disadvantages	Usage†
		Capital	O&M (date)		
Electrostatic precipitator	91-99+	\$0.4-2.3 x 106 \$0.9-4.2/CFM	\$0.05-0.7/CFM/Yr (1971)	Economical w/simple, low cost operation. High initial cost, large space requirements, can't be efficiently used on explosive gases; may foul with SO_2 sensitive to flow variation.	Widespread usage in recovery and power boilers; sometimes used in lime kilns
Cyclone separator	65-99+	\$0.59-1.0/CFM plus installation		Efficient on coarse particulates & high concentration. Excellent as a primary collection system.	Typical in lime kilns; also found in coal and wood fired power boilers, and some recovery furnaces
Fabric filter	99+	\$0.91-4/CFM	0.12-0.32/CFM/Yr (1971)	Useful on gases of low humidity, volume, and temperature, and to trap particulates which are economical to recover.	No extensive use in any process
Black liquor oxidation(BLO)	50-100(TRS) 95-99(H_2S) 50-100(TRS)	\$350-1000/TPD	\$10-200/TPD/Yr (11/73)	Can provide better performance in recovery boiler, for chemical recovery.	Frequently used

(continued)

TABLE 61. (Continued)

Device	%* Efficiency (pollutants)	Cost#		Advantages/disadvantages	Usage†
		Capital	O&M (date)		
Mist pads	70-90	-	-	-	Used for some smelt dissolving tanks
Incineration	-	$108-162/TPD	$0.01-0.05/TPD/Yr (10/76)	-	Lime kiln incineration relatively widespread

*Unless otherwise specified, efficiency is based on particulates.

#Cost figures based on TPD (tons of product per day) and cfm (cubic feet of gas treated per minute). O&M (operation and maintenance) costs do not include any credits (such as any chemical or heat recovery).

†Usage is based on total industry capacity.

To minimize odors from this area, adequate condensation of these gases must be provided. This requires that sufficient capacity be provided to handle peak gas flow, and that the heat recovery system is adequate. The heat recovery system should have proper controls and instrumentation and heat exchanger surfaces should be clean. If possible, the discharge (blow) of the digesters should be controlled so no surge of gases occurs; this can be accomplished by decreasing the blow pressures.

In the pulping of softwoods, turpentine can be recovered from the blow gases. If the condensate outlet temperature can be decreased, the odor from the turpentine recovery system can be decreased. Gases can also be incinerated.

By evaporation, black liquor (spent cooling liquor) may be concentrated to combustion strength. Two methods of evaporation are currently in use: direct contact evaporation with hot flue gases from the recovery boiler; and indirect evaporation with stream. The former method can lead to odor problems when the black liquor is burned in the recovery furnace. Bringing the sulfide concentration down to near zero will greatly decrease the odor caused by hydrogen sulfide. This can be accomplished by oxidizing the weak black liquor with air or oxygen before evaporation.

The use of rotary drum filter pulp washers instead of diffusion washers also decreases the odor at the evaporators by some oxidation of the liquor, but this transfers the problem to the washers, as more odor will be noticed there.

In the oxidation of black liquor, sufficient oxygen transfer from the air must occur to ensure efficient oxidation. It is also important to increase the capacity for black liquor oxidation when the pulping capacity increases. Proper liquor and air flow rates, and sodium sulfide (the compound to be oxidized) loadings must be maintained depending on the type of oxidation system employed.

As in any combustion process, the burning of spent cooking liquor in a recovery boiler should have an optimum amount of air for complete combustion. If any auxiliary fuel is required, as may be the case in the sulfite process, this quantity too should be constantly checked to ensure that fuel is not being wasted and causing an increase in air emissions. Nitrogen oxides are a major pollutant in the burning of spent liquor from the magnesium based sulfite process. These discharges can be minimized by evaporation of the spent liquor to a minimum solids content necessary to support combustion, and by operating the boiler at a relatively low firing rate to minimize heat release.

After cooking chemicals are reclaimed through the oxidation process and new liquor is made up through lime addition, the lime sludge containing calcium carbonate obtained after adding lime (calcium oxide) is burned to recover calcium oxide. Various sulfur compounds are emitted in this process; however, TRS discharges can be minimized by maintaining excess oxygen levels of at least 4 percent by volume. A high temperature and long retention time of lime sludge in the kiln also decreases the amount of reduced sulfur compounds discharged. The handling of lime dust does cause emission of particulates, but these can be decreased by containing the sources of the emission, and by wetting the lime dust to prevent it from becoming airborne. Care must be taken not to overwet the lime dust, as this can create a very wet sludge which would then have to be handled.

Gases can be incinerated at various points in the mill. Preventive maintenance is also important and an effective way to control atmospheric discharges. Systems should be constantly checked for leaks, and any fouled parts should be cleaned.

The increased use of wood waste as a fuel source has led to a need for research into the combustion characteristics and emissions from hogged fuel boilers. Particulate emissions from hogged fuel boilers can be reduced through proper fuel characteristics and careful combustion control. Research in these areas has been recently conducted at Oregon State University leading to the following conclusions:(165)

- There is a significant interaction effect on combustion efficiency between fuel size, fuel moisture content, levels of excess air, and location of the inlet air for combustion.

- The effect of fuel size on combustion efficiency is limited. Test data indicates that fuel size fractions less than 1/4 inch have generally lower emissions of unburned solid carbon than larger size fractions.

- Fuel moisture effects are minimal on combustion efficiency for some modes of operation, but may be highly significant for small size fractions coupled with air fed principally as undergrate air. The effects of moisture are negligible when the undergrate air flow is limited to low levels and the majority of the combustion air flow is provided as overfire air.

- The carryover of unburned carbon from the combustion zone is roughly linearly related to fuel feed rates (heat release rates) when air is supplied as undergrate air. For normal operation of spreader-stoker combustion systems, one can expect carryover concentrations from the combustion zone of 3 grains/scf at heat release rates of 0.52 million BTU's per square foot of grate area. The concentration may approach 5 grains/scf at heat release rates of 0.72 million BTU's per square foot of grate area.

- Wood fuels are roughly 80 percent volatile on a dry basis. It is predicted in theory and now shown in practice that combustion efficiency and stack gas opacity can be improved by taking advantage of this characteristic of the fuel by burning it in two-stage combustion; that is, by strictly limiting the flow of undergrate air to levels approaching 10 percent of the total air flow and making up the remainder of the combustion air by overfire air. Thus, the solid carbon portion of the fuel is allowed to burn to CO_2 on the grate with very low vertical gas velocities. The volatile portion of the fuel is burned above the grate at the level of the overfire air inlet ports. This mode of operation permits combustion at relatively low levels of excess air. This finding is perhaps the most significant of the research effort to date.

Wood Preserving Industry

Production controls can also be employed in the wood preserving industry to reduce air emissions.

An enclosing hood or building could be used to collect vaporized organic emissions from creosote and oilborne preservatives. The hood would need to cover the entire end of the retort, a section of track and switches, and a complete tram or trams. Such a structure, perhaps exceeding 60 meters in length, would require enormous gas exhaust rates to supply work-place ventilation needs, and the associated emission control devices would also be very large. Particularly in retrofit at older mills, such hooding and ventilation systems could be economically unfeasible. Alternatives exist, however, as are discussed below.

Low boiling point organics may be controlled by reducing the temperature of the freshly treated wood from 82 to 45°C. A header containing spray nozzles may be mounted a few centimeters from the open end of the retort, so placed as to blanket the entire opening and emerging tram loads with water sprayed at about 1 cu m/min. A switch engine slowly moves the emerging tram cars from the retort through the spray blanket. Speeds no faster than 5 m/min are recommended.(162) In effect, the air pollution problem becomes a water pollution problem. Spray water must be collected, skimmed to remove insolubles, and cooled prior to recycling. Following skimming, creosote concentration is about 2 ppm. Spray water is heated several degrees during each use cycle, unless the final vacuum period is extended to an hour or more, a spray tower or pond is employed, or a large capacity water system is used.

Odor emissions from the Ammonical Copper Arsenate (ACA) preserving process can effectively be controlled from the retort. A final hour at 0.7 kg/sq cm (gage) is adequate.(162) Ammonia emissions from the barometric hot well and preservative mixing tanks may be controlled by sealing and/or venting equipment.

Flow rates at ACA wood preserving plants must be as low as possible, to maximize scrubber efficiency and reduce odor. A packed tower of 46 cm diameter packed with 0.2 cu m of 2.54 cm Raschig rings has been used at one mill.(162) Recirculating water concentrations should not exceed 1.5 percent NH_3 by weight.

Workplace safety procedures including automatic mixing of preservatives can minimize the potential for inhalation of toxic materials.

SECTION 5

SOLID WASTES

SOLID WASTE SOURCES AND CHARACTERIZATION

Introduction

Solid wastes are generated from a number of sources in the wood products industry. In general, documentation concerning the specific quantities of solid waste generation is sparce, although the majority of the waste poses no environmental hazard when properly disposed. Hazardous solid waste generation in the wood products industry is estimated in Table 62. A characterization of non-hazardous and hazardous solid waste production by the wood products industry has been performed.(166) The following discussion is largely taken from this reference.

Pulp , Paper, and Paperboard Industry

Solid wastes generated by the pulp, paper, and paperboard industry originate from wastewater treatment, wood processing, power generation, and personnel activity.

According to a 1974 U.S. Department of Commerce estimate, total solid waste generation by the pulp, paper, and paperboard industry was 560 to 630 pounds of solid waste per ton of production. The largest single source of waste is wood processing, which accounts for about half the total. This waste consists primarily of bark with some wood and dirt included. Much of this waste may be burned in a hogged fuel boiler for power generation. There are apparently no statistics concerning the amount of wood processing waste currently being used for power generation.

Wastewater treatment facilities produce both primary and biological sludges which are usually dewatered prior to disposal. Biological sludges are more difficult to dewater mechanically and often require pretreatment. Final solids content varies from 20 to 40 percent. The amount of wastewater treatment plant sludge generated depends on a number of conditions including: 1) raw waste characteristics; 2) the existence and efficiency of primary clarifier; 3) the type of biological treatment; and 4) the existence and efficiency of secondary solids removal.

Primary clarification can remove up to 80 percent of the raw suspended solids load, depending on particle size distribution. Prior estimates have

TABLE 62. HAZARDOUS SOLID WASTE SUMMARY

		U.S. Production (M. tons/yr)		
Source	Solid waste	Total waste	Hazardous constituents	Toxicity data
Alkaline pulping	Slaker and unburned lime rejects;	711,800	NaOH Trace-148,000	Orl-rat LD-50* 40 mg/kg
			Na_2S Trace-59,000	No data
Wood preserving	Creosote-oil emulsion	230-930	Creosote 1.1-4.6	Orl-rat LD-50* 725 mg/kg
	Penta-oil emulsion	600	Pentachlorophenol 3.0	Orl-human LDL_o: 29 mg/kg suspected carcinogen
	Water-soluble preservative residues	27-140	Heavy metal salts 0.27-1.4	Category I# material

*LD-50 = Lethal dosage for 50-percent survival, expressed in mg/kg of body weight.

#A substance having an LD-50 in the range of 0-50 mg/kg or a known carcinogen.

Source: Battelle Columbus Laboratory (166)

placed primary sludge production in the pulp, paper, and paperboard industry in the vicinity of 20 million lb/day (dry basis).(80,167) Activated sludge treatment typically produces 0.7 lb of solids/lb of BOD_5 removed, while aerated stabilization typically produces 0.2 lb solids per lb BOD_5 removed.

Power generation can result in significant quantities of solid waste, particularly when large amounts of hogged fuel (wood processing waste) is burned. This solid waste consists of bottom ash, cinders, and fly ash.

Industry personnel are reported to generate about 0.55 lb of refuse per employee per shift. This waste is similar to municipal refuse.

Solid wastes generated by alkaline pulping include slaker grits, unburned lime rejects, and green liquor dregs, while those from sulfite pulping include ash washers and cooling filters.

Pulp, Paper, and Paperboard Wastewater Treatment--

The total primary sludge produced in the U.S. pulp, paper, and paperboard industry in 1971 was estimated to range from 1,672,000 to 3,575,000 metric tons (on a dry weight basis).(168) To obtain the total primary wastewater treatment solid waste, sludge incineration ash was added to the dewatered sludge transported to land disposal. The total primary wastewater treatment solid waste was estimated to range from 1,220,000 to 2,616,000 metric tons (on a wet basis).(168) Biological treatment facilities were not widely used in the pulp and paper industry at the time of the report. Biological sludge from the pulp, paper, and paperboard industry is estimated to be approximately 40 percent of primary sludge production (dry weight basis).

Primary sludge contains both organic (fibers, starch, inks, etc.) and inorganic (coatings, fillers, and pigments) constituents. Commonly used fillers and coatings include Kaolin clay, calcium carbonate, titanium dioxide, zinc oxide, diatomaceous silica, hydrated aluminas and barium sulfate. All of these compounds have an aquatic toxicity, median toxic limit 96 hour of over 1,000 ppm. However, some of the inorganic pigments and organic dyes and lakes (an organic dye on an inorganic carrier) are toxic. Many of the inorganic pigments are heavy metal salts (lead, chrome, molybdenum, cadmium, and mercury), and commonly used organic dyes and lakes are azo compounds. Also, cobalt, lead, and zinc compounds are commonly used as drying catalysts in ink vehicles.

The only information obtained on the amount of toxic constituents contained in primary wastewater treatment sludges was analyses of the metal content in several different papermill sludges and ashes, as shown in Tables 63 through 65. As a basis for comparison, the metal content of soil samples (geometric mean of 863 samples) and municipal sludge (median of 33 samples) is given in Table 66. The heavy metal content of the papermill sludges ranged from below background levels (i.e., lower than the mean soil concentrations) to approximately 2 to 12 times the mean soil concentrations. In contrast, the median concentrations of heavy metals in municipal sludges ranged from 30 to 70 times the soil concentrations.

One must conclude from the very limited data that primary sludge from some papermills may contain hazardous levels (above background levels) of heavy metals, but the levels would not be nearly as great as in municipal sludge. One would also expect large mill-to-mill variations in the concentration of heavy metals, but in general, sludges from mills utilizing secondary fibers would contain higher levels than sludges from primary fiber mills. In some cases, the concentration of heavy metals in secondary sludges may also be higher than background levels, depending on the initial level of metals in the form of sawdust and some wood scrap from splintering.

TABLE 63. ANALYSES OF SEVERAL SLUDGES FROM PULP, PAPER, AND PAPERBOARD MILLS: 1977

	Sludge		
	Mill A primary*	Mill B primary#	Mill B primary plus secondary
Ash, %	21	2.1	16.2
BOD, %	15.5	3.5	4.4
COD, %	34.9	22.0	25.3
Total K-nitrogen, %	1.01	0.03	1.44
NH_4-nitrogen, mg/kg	0.07	0.01	1,600
NO_3-nitrogen, mg/kg	0.04	--	--
Total P, mg/kg	365	100	1,300
Soluble P, mg/kg	68	--	--
Fe, mg/kg	2,060	1,553	227
K, mg/kg	3,710	132	372
Al, mg/kg	8,850	580	783
Ca, mg/kg	2,950	11,500	379
Mg, mg/kg	2,980	348	170
Na, mg/kg	9,550	4,201	2,935
Zn, mg/kg	185	97.5	20.7
Ni, mg/kg	31	27	--
Cu, mg/kg	146	16.8	4.7
Cr, mg/kg	129	13.3	8.9
Pb, mg/kg	189	23.8	2.4
Hg, mg/kg	--	--	0.095

*Mill A - Sludges resulting from the production of linerboard made from waste corrugated boxes picked up in a large metropolitan area.

#Mill B - Sludges resulting from the production of bleached kraft pulp, groundwood pulp, and papermaking.

Source: SCS Engineers, Inc. (169)

TABLE 64. ANALYSES OF SEVERAL SLUDGES FROM PULP, PAPER, AND PAPERBOARD MILLS

	Total combined sludge* (mg/kg) oven dry basis	Papermill sludge# (mg/kg) oven dry basis	Waste activated sludge (WAS) (mg/kg) oven dry basis	Pulp mill† plus WAS (mg/kg) oven dry basis
Chromium	150	140	110	160
Copper	40	30	50	50
Lead	28	12	60	46
Nickel	17	14	25	20
Zinc	340	300	460	385
Titanium	19,500	18,900	10,600	20,200
Cadmium	2.3	2.5	4.0	2.0
Phosphorus	4,000	1,600	4,650	6,800
Mercury	0.18	0.32	0.30	0.02

*Total combined sludge - a mixture of all sludges produced in the treatment plant.

#Papermill sludge - sludge from the paper machine and coating departments which settles out in the papermill primary clarifier.

†Pulp mill plus waste activated sludge (WAS) - a mixture of sludges from the pulp mill clarifier and excess biological sludge.

Source: SCS Engineers, Inc. (169)

TABLE 65. ELEMENTAL ANALYSIS OF PRIMARY TREATMENT SLUDGE ASH

Sample source* and date	Over 10 percent	1 percent to 10 percent	0.1 percent to 1 percent	0.01 percent to 0.1 percent	0.001 percent to 0.01 percent	Below 0.001 percent
Primary treatment plant coil filter - 2/1/68-3/17/68	Si	Al, Fe, Na, K, Ti	Mg, Mn	Pb, Ba, Sr	Zr, Sn, Cr, Cu, Ni, B	
Primary treatment plant coil filter - 6/5/68-7/2/68	Si	Al, Fe, Ca, Na, K, Ti	Mg, Mn	Ba, Pb, Sr	Zr, Cr, Mo, Cu, Ni, B	--
Primary treatment plant press cake - 4/1/70-6/23/70	Si, Al	Fe, Mg, Ca, Na, Ti	K	Mn, Pb, Cu, Ba, Sr	Zr, Cr	Ni

*Source of sludge - integrated pulp and papermill producing bleached kraft and sulfite grades. Almost half of the ash in the sludge comes from the wood-mill effluent; % ash (O.D. basis) ranged from 17.4 to 29.7 percent during the sample period.

Source: Aspitarte, T.R. (170)

TABLE 66. COMPOSITION OF SOILS AND MUNICIPAL SLUDGES

Element	863 soil samples in the contiguous United States(169) Geometric mean, ppm	 Geometric deviation	33 municipal digested sludges(171) Median value, ppm
Al	45,000	2.41	--
B	26	2.05	--
Ba	430	2.06	--
Be	0.6	2.49	--
Ca	8,800	3.92	--
Co	7	2.21	--
Cr	37	2.32	1,100
Cu	18	2.28	1,250
Fe	18,000	2.30	--
Ga	14	2.11	--
Hg	--	--	6.6
K	12,000	2.71	--
Mg	4,700	3.19	--
Mn	340	2.70	--
Na	4,000	4.11	--
Ni	14	2.26	410
P	250	2.74	31
Pb	16	1.96	830
Ti	2,900	1.87	--
V	56	2.16	--
Zn	44	1.86	2,800
Zr	200	1.90	--

No hazardous solid wastes are believed to be generated by veneer/plywood processing.

Alkaline Process Solid Waste--

The quantity (1971 production) of chemical pulping solid waste (see solid waste generated section) from the alkaline process is estimated to range from 405,000 metric tons to 540,000 metric tons.(168) Approximately 75 percent of the total waste generated was in the South Atlantic and South Central regions.

Both green liquor dregs and slaker rejects contain widely varying levels of sodium hydroxide and sodium sulfide. The concentration of both constituents was estimated to range from trace amounts for newer, more modern mills to as much as 32 percent (for NaOH) for some older mills.(172) Both sodium hydroxide and sodium sulfide are water soluble and could be released to the environment by leaching. In addition, sodium sulfide can hydrolyze under acidic conditions to form hydrogen sulfide which could be released by evaporation. None of the other components in chemical pulping solid wastes from the sulfate process ($CaCO_3$, Na_2CO_3, CaO, carbon, iron compounds, and various other metal oxides) can be considered hazardous by the criteria selected for this study.

Sulfite Process Solid Waste--

An estimated 17,106 metric tons of the chemical pulping solid waste was produced from the acid sulfite process in 1971.(168) These wastes primarily consist of inerts (SiO_2, CaO, FeO, etc.) plus some oxide of the base cooking chemicals. In magnesium-base sulfite pulping, small amounts of magnesium sulfite are lost in the chemical recovery cycle.

Veneer/Plywood

Three types of solid waste are produced by the veneer/plywood industry: 1) bark; 2) wood scraps; and 3) sawdust.

The first step in the production of veneer is to debark the logs. This may be done by one of several methods, but all methods result in the production of large quantities of bark.

Wood scraps are generated in several places during the production of veneer/plywood. The veneer cutting operation produces some scrap due to irregularities in the logs. As the green veneer is moved through dryers, some fracturing of the veneer occurs so that the dryers have to be cleaned periodically to remove the wood waste. After the plywood lamination process, the sheets have to be trimmed to size which generates some trimming scrap. Finally, the inspection process detects some flawed pieces in which the flaws have to be removed, or the entire sheet scrapped if the flaws are bad enough.

One of the last production steps involves a sanding operation which may be performed on one or both sides of the veneer or plywood, depending upon its ultimate use. This produces a considerable quantity of solid waste in the effluent and impacts the degree of solids removal during primary treatment.

Several methods are not in use to dispose of the solid waste from the veneer/plywood operation, although no information was obtained relative to the amounts of material disposed by each method. When large sheets of veneer or plywood have to be removed because of excessive flaws, these may be shipped and the chips used in products such as particleboard. Since all of the wastes are burnable, they may be burned at the site, using the heat as an energy source where the facilities are available. Where burning is not possible, the solid waste is hauled to a landfill.

Particleboard

The particleboard industry is primarily a consumer of solid waste rather than a producer since much of the raw material used to produce particleboard consists of waste products from other wood processing industries. However, there are three types of solid waste produced: 1) undersized wood particles; 2) trimming scrap; and 3) sawdust.

Prior or subsequent to particle preparation, it is usually necessary to classify the wood by size. The classification is done primarily to reject particles which, if allowed to remain, would increase the resin requirements, present problems during manufacture, or produce defects in the product. The rejects which are too large are recycled back into a system such as a hammermill which reduces the size. The fines which are unacceptable for the process are discarded. Trimming scrap and sawdust are generated during finishing of the product. No hazardous solid wastes are generated by the particleboard industry.

Sawmills and Planing Mills

Sawmill operations produce significant quantities of three basic types of solid wastes: 1) residue which can be chipped; 2) bark residue; and 3) sawdust. For example, in a recent study on black oak logs, the mill output was 55 percent lumber; 20 percent chipped residue; 15 percent bark residue; and 10 percent sawdust.(173) Another study on yellow poplar logs showed 54 percent lumber; 15 percent bark residue; 18 percent chipped residue; and 13 percent sawdust.(174) If these studies are typical, almost half of the weight of logs delivered to sawmills ends up as one of the three waste products.

Because of the large amount of waste generated, much effort has been devoted to finding uses for this waste. For example, wood chips are sold to pulp mills to be converted into paper products. Bark residue is screened, washed, and marketed as soil amendus, mulch, and ground cover. Sawdust is sold for mulching and livestock bedding or burned as fuel. No information was located indicating the total amounts of waste product sold for these various purposes.

No hazardous solid wastes are believed to be generated in this subcategory.

Wood Furniture and Fixture

There are three types of solid waste generated by the wood furniture and fixtures industry: 1) miscellaneous wood waste; 2) finish particles collected in spray booths; and 3) suspended solids in water effluent.

Miscellaneous wood waste (scrap wood, sawdust, etc.) is generated at various points in the furniture manufacturing process.

Finish particles are solid particles of the various materials (shellacs, lacquers, varnishes, drying oils, etc.) used to protect and beautify wood furniture. These materials are applied in a spraying operation conducted in booths which contain and collect the overspray and thus provide fire and health protection. In water wash spray booths, the solids are removed from the air stream by forcing the air through a series of water sprays or by collecting the solids in a water pan. These booths are typically cleaned once a week by draining, and the settled solids are manually removed. With some finishes, the solids are salvaged and reprocessed.

The primary sources of wastewater from the furniture manufacturing process are spray booths, laundry facilities, and glue cleanup operations. The solids concentration in wastewater from spray booths is quite high with the greater percentage of the solids being dissolved and nonvolatile. The solids content of glue wastewater is almost entirely volatile and for the most part dissolved.

No hazardous solid wastes were identified from the wood furniture and fixtures industry. A representative of the Southern Furniture Manufacturers Association was contacted and to his knowledge no studies have been made concerning the solid waste from the furniture manufacturing industry. He was also of the opinion that the industry does not generate any hazardous solid waste.

Gum and Wood Chemicals

The following discussion of the solid wastes from the gum and wood chemical industries, including their constitution, method of preparation, and current disposal methods are organized by product category. The wastes are therefore generalized by process, such as essential oils manufacture, but the solid wastes produced at any given location may vary in content depending on which of the many individual processes are actually used.

Char and Charcoal Briquettes--

The only solid waste reported from the manufacturer of char and charcoal briquettes is fugitive solids from cyclones used to convey the powdered char. These solids are usually carried away from the plant site in rainwater runoff. It is presumed that these wastes are not toxic. They are the non-volatile solids which result from heating hardwood in the absence of air (charcoal).

Gum Rosin and Turpentine--

The gum rosin and turpentine manufacturing process begins by melting and filtering the crude gum. The filtered material includes dust, leaves, bark, etc. These solids are landfilled.

Wood Rosin, Turpentine and Pine Oil--

In the first process step, pine stumps are washed with water to remove dirt, etc. The water and dirt are placed in a settling pond which is periodically dredged, and the solids are landfilled.

Tall Oil Rosin, Fatty Acids and Pitch--

No mention of solid wastes from the crude tall oil refining process could be found.

Essential Oils--

The cedarwood oil process has been described as representative of the various essential oil manufacturing processes.(176) Dust from planing mill and sawmill operations on cedar trees are blended in the first step of the process. Some dust escapes in this operation. The dust is removed from the site in rainwater runoff which is carried through the storm sewers. The dust is assumed to be nontoxic.

A second source of solids occurs when the extracted cedar wood oil is mixed with clay and then filtered to remove color bodies. The clay filter cake is landfilled.

It is assumed that the cake is not highly toxic. For instance, cedrol, which occurs in cedarwood oil is listed in the Merck Index and no reference to lethal dose or other medical data is given.(177) However, cedar leaf oil, which results from a separate small scale industry, contains d-alpha-Thujone which has an oral-rat LD50 of 850 mg/kg.(178) Other essential oils, prepared under similar conditions, may result in small amounts of toxic waste. No data are available.

Rosin Deviations--

Rosin derivative processes include isomeization, oxidation, hydrogenation, dehydrogenation, polymerization, salt formation, and decarboxylation. Although not every process has been studied, in general these processes do not involve the production of solid wastes.

Hazardous Wastes--

There are apparently little or no toxic solid wastes being emitted by the wood and gum chemical industries. The only identified toxic component, d-alpha-Thujone, is typical of the types of materials which may be landfilled in very small quantities in the manufacturing of essential oils. There may be others which have not been identified but all of them would be present in very small amounts in the solids and the volume of solids themselves would also be small. Exact figures on quantities of solids and concentrations of toxic components are unavailable. The amounts of various products produced are unknown.

The principal route of possible exposure to the public of these materials would be leaching from landfills. The leaching process is probably not rapid since the toxic organics would be sparingly soluble in water and absorbed on water insoluble clay filter cakes.

Wood Preserving

The amount and composition of the solid waste produced in a wood preserving plant is dependent on the type of preservative used. There are three general classes of preservatives: 1) inorganic water-soluble preservatives (heavy metal salts); 2) pentachlorophenol in oil; and 3) creosote.

All the water effluent from plants employing water-soluble preservatives is recycled back to the process. Only very small quantities of solid wastes are generated in these plants from the accumulation of inert residues (silt and grit) present in the untreated wood. These wastes are disposed of on an infrequent basis (1 to 5-year period) in sanitary landfills or where available in approved chemical landfills. A typical one to three-cylinder plant would produce from one to five 55-gallon drums (300 to 1,500 kg) of solid waste per year. The solid waste from these plants is composed primarily of sand and grit (typically 75 to 90 percent), the remainder being mostly wood chips and sawdust. Heavy metal salts comprise less than 1 percent of the waste.

Emulsion formation is a frequent problem in preservative plants using pentachlorophenol in oil. The emulsions are formed during the treatment process (in the penta worktanks) and exit the process through water effluent separators. Polyelectrolytes are frequently used by the industry to minimize the emulsion problem. Emulsions are typically greater than 90 percent water with varying amounts of sand, grit, and wood chips. The pentachlorophenol content of the emulsions is usually less than 0.5 percent. A typical one-cylinder plant treating with pentachlorophenol in oil would generate less than one 55-gallon drum of solid waste (emulsions) per month.

The amount of solid waste generated by treatment plants using creosote as the preservative depends on the nature of the creosote solvent. There are three types of creosote-solvent systems commonly used by the industry: 1) creosote in petroleum (CPS); 2) creosote in coal-tar solution; and 3) creosote only.

Emulsion formation is a problem with CPS due to the proximity of the specific gravity of the solution to that of water (creosote is more dense than water and the petroleum solvent is less dense). Generally, CPS emulsions are dehydrated, and the oil is recycled to the treatment process.

Treatment with creosote in coal tar or creosote only usually results in minimal emulsion formation and little solid waste generation with the exception of soil and inerts. This solid residue is periodically removed from process tanks and equipment and disposed of by: 1) mixing with asphalt for road construction on plant property; 2) harrowing into soils to permit biological degradation; or 3) landfilling.

A typical three-cylinder creosote treatment plant would generate from one to four 55-gallon drums of solid waste per month. However, disposal of the waste would be on a much less frequent basis (perhaps every year or two).

The largest single factor in determining the amount of solid waste generated by a wood preserving plant is the soil and sand content of the wood. Creosote may contain variable amounts of insolubles which also affects the amount of solid waste generated.

The average yearly production of process solid wastes from the wood preserving industry is estimated in Table 67. This data was estimated from waste-generation factors (e.g., gallons of waste produced per treatment cylinder) supplied by the Joint Chairman of the American Wood-Preservers' Association and the American Wood-Preservers' Institute and from a rough estimate of the number of treatment cylinders used for the application of each type of preservative solution. It should be emphasized that the production figures given in Table 67 should be viewed as crude estimates of the actual amounts and that many of the solid wastes are generated on a periodic basis, in some cases periods as long as five years.

The amounts of hazardous solid waste generated by the wood preserving industry are also given in Table 67. The hazardous components consist of pentachlorophenol, creosote, and heavy metal salts. The total amount of these components generated nationally was estimated to average less than nine metric tons per year. The primary route of exposure to the general public is leaching of the hazardous components.

AVAILABLE SOLID WASTE DISPOSAL TECHNOLOGY

Techniques available for solid waste disposal include: incineration, composting, pyrolysis-gasification, ocean dumping, and landfill.

Incineration is a preferred method for disposal of organic wastes with a high solids content. For the forest products industry these include log sorting and mill yard wastes, and organic sludges when sufficiently dewatered. This will normally require the more expensive filter press method following vacuum filter or horizontal belt dewatering.

Composting is an emerging technology that theoretically could be applied to pulp, paper, and paperboard mill waste treatment sludges. By this method, sludge is converted to inert organic material which may be used as a soil conditioner. The method has not received attention in the pulp, paper,

TABLE 67. POTENTIALLY HAZARDOUS SOLID WASTES FROM THE WOOD PRESERVING INDUSTRY

Total process solid waste metric tons/yr	Total potentially hazardous constituents metric tons/yr	Average concentration mg/kg	Toxicity data
Creosote-oil emulsion 230-930	Creosote 1.1-4.6	5,000	Orl-rat, LD50:725 mg/kg Orl-dog, LDLo:600 mg/kg
Penta-oil emulsion 600*	Pentachlorophenol 3.0	5,000	Orl-humn, LDLo:29 mg/kg Orl-rat, LD50:50 mg/kg suspected carcinogen
WSP residues# 27-140	Heavy metal slats† 0.27-1.4	10,000	Category I - suspected carcinogen

*Estimated maximum amount.

#Residues from treatment plants using water-soluble preservatives.

†Typical components: Copper oxide, chromic acid, arsenic pentoxide or trioxide, chromium trioxide, chromated zinc chloride; acetic acid, boric acid, fluorides.

Source: American Wood Preservers' Association (179) and paperboard industry, perhaps due to the large volumes of sludges produced and the lack of a market for the corresponding volumes of compost.

Pyrolysis-gasification is an emerging technology that may play a future role in solid waste disposal. Commercial scale units from which economics operating experience may be obtained have yet to be demonstrated.

Ocean dumping is not widely practiced in the industry and it is not an acceptable technique due to environmental consequences.

Land application of wastewater treatment plant sludges has received attention recently. In this method, the sludge is aplied to a field which will be used for agricultural production. The organics, nutrients and bulk of the sludge serves to enhance the crop production capacity. A prerequisite for the technique is to have adequate and suitable land in reasonable proximity to the plant.

Landfills are the most prevalent means of solid waste disposal in the industry. The environmental safety procedures practiced at landfills can vary widely, and knowledge of proper landfilling practices has increased widely in recent years.

SOLID WASTE LEGISLATION

The Solid Waste Disposal Act, as amended by the Resource Conservation and Recovery Act of 1976 (PL 94-500), contains the authority for the EPA to establish land disposal regulations.

Land Disposal Regulation and Guidelines

Subtitle D of RCRA contains provisions for land disposal of all solid wastes that are not covered by the hazardous waste regulations. EPA has published final and interim final regulations (Federal Register, Vol. 44, Thursday, September 13, 1979) establishing criteria for classification of solid waste disposal facilities and practices. The criteria are used to identify those facilities which are considered "open dumps" for purposes of the state solid waste management planning effort supported by the EPA; which calls for the closing or upgrading of land disposal sites identified as "open dumps" under Section 4004. In addition, all sites which do not meet these criteria are considered open dumps and are to be prohibited.

The EPA under the authority of the Solid Waste Disposal Act, as amended by RCRA of 1976, published proposed guidelines and regulations for landfill disposal of solid waste in the Federal Register, Volume 44, Monday, March 26, 1979. The guidelines were established to suggest preferred methods for the design and operation of facilities which utilize landfilling techniques.

Hazardous Waste Regulations

Since sludges generated by the wood preserving processes that use creosote and/or pentachlorophenol fall into the hazardous waste category as outlined by RCRA (May 1980), several criteria will need to be met by the industry for disposal, transportation and handling.

Table 68 is a listing of the Federal Regulations published under Subtitle C and lists where each regulation can be found in the Federal Register.

DISCUSSION - SOLID WASTE

Current solid waste disposal practices in the wood products industry consist primarily of landfilling. Combustible wastes are often burned to recover their heat value, although the resulting ash must still be disposed of.

Wastewater treatment plant sludges are usually dewatered prior to land disposal. When the environmental and operating conditions of the sanitary landfills or land application site for solid waste are adequate, the resulting impacts should be minimal. Currently, there is no detailed information concerning environmental and operational aspects of land disposal sites for the industry.

Low ash wastewater treatment plant sludges, if dewatered sufficiently, can also be burned for heat recovery and volume reduction. Additional research concerning the technical and economic feasibility of this approach is warranted, that addresses particularly the effects on the combustion/-boiler system and resulting air emissions.

TABLE 68. FEDERAL HAZARDOUS WASTE REGULATIONS

40 CFR	Corresponding RCRA section	Federal Register date
260	Definitions used in other parts corresponding to the Sections 3001 through 3004 rules, and general provisions applicable to these parts.	5/19/80 Part II
261	Section 3001: Identification and listing of hazardous waste	5/19/80 Part III
262	Section 3002: Standards applicable to generators of hazardous waste	5/19/80 Part V
263	Section 3003: Standards applicable to transporters of hazardous waste	5/19/80 Part VI
264	Section 3004: Standards applicable to owners and operators of hazardous waste treatment, storage, and disposal facilities	5/19/80 Part VII
265	Section 3004: Interim status standards applicable to owners and operators of hazardous waste treatment, storage, and disposal facilities	5/19/80 Part VII
122 and 124	Section 3005: Permits for treatment, storage, and disposal of hazardous waste	5/19/80 Part X
123	Section 3006: Guidelines for authorized state hazardous waste programs	5/19/80 Part X
-	Section 3010: Preliminary notification of hazardous waste activity	2/26/80 (45FR12746)

Source: Federal Register, Monday, May 19, 1980

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APPENDIX A.

PRODUCTION PROCESS DESCRIPTIONS

INTRODUCTION

The following process descriptions for the pulp, paper, and other wood products industries have been taken directly from referenced documents in order to present an overview of production practices as they affect the industries' pollution control requirements.

PULPING PROCESSES (1, 2)

Unbleached Kraft

Wood, the fiber raw material of unbleached kraft pulp, arrives at the pulp mill as logs or as chips. Barked logs can be chipped directly for use. Bark is removed from unbarked logs in a wet or dry process and the logs are then chipped for conveyance to the digester, a large steel pressure vessel heated with steam to approximately 150°C. Here the chips are cooked in either a batch or continuous operation to dissolve lignin and separate the cellulosic fibers. The cooking liquor contains a mixture of caustic soda and sodium sulfide, which necessitate, because of high chemical costs and high liquor concentrations, a chemical recovery system which is integral to the process. This system and its role in the preparation of cooking liquor are described in ensuing paragraphs.

The unbleached kraft process is described as a full-cook process, since cooking is completed to the point at which the wood will be fiberized upon being blown from the digester. In modern practice, the pulp is ejected to a blowtank.

The pulp, along with the spent cooking liquor is then transferred to a brown-stock chest, or tank, and thence to vacuum drum washers or continuous diffusers where the spent cooking liquor is separated by counter-current washing. In older mills, the pulp is blown directly to the diffusers from the digester.

Chemical recovery necessitates a high degree of liquor separation with as little dilution as is possible to minimize heat requirements of evaporation. Three stages of washing, which may employ blow tank condensate reuse are common but, in some cases, four are used. In some newer installations a combination of vacuum washers and diffusers is employed. Some continuous digesters contain liquor separation and diffusion washing zones within the digester body, and in many kraft mills, the pulp is screened and/or refined prior to brown-stock washing to effect certain economies in washing and improvements in pulp quality.

After washing, the pulp is diluted and then screened to remove knots, uncooked chips, pitch particles, etc., and is ready for production of unbleached paper and paperboard or thickening to a high consistency for further processing, storage, or lapping for shipment.

The kraft pulping process is illustrated in Figure 10.

Weak black liquor comes from the washing operation and contains about 10 to 16 percent solids. In addition to the inorganic cooking chemicals, it contains organic wood constituents separated in the pulping process. The weak black liquor is concentrated to about 45 to 50 percent solids in long-tube multiple-effect evaporators and the resulting viscous mass is called strong black liquor. This is then concentrated further to a consistency of 60 to 65 percent solids in the recovery furnace contact evaporator or in a concentrator.

Cooking chemicals lost in pulping and washing are replaced with a make-up chemical, usually sodium sulfate, or a residue with a high content of this salt. Acid sludge from oil treatment, raffinate from by-product production, NSSC waste liquor, and ash from incineration of NSSC liquor are examples of such residues. Salts captured from the recovery furnace stack gases are also reintroduced into the system Sulfur and caustic soda are sometimes used to adjust the sulfidity.

The strong black liquor is then burned and the heat recovered in a specially designed boiler. During burning, the organic sodium compounds are converted to soda ash and sulfates reduced to sulfides on the floor or reducing section of the furnace. The molten smelt of salts is dissolved in water to form green liquor. This is clarified by sedimentation and then causticized with lime to convert the soda ash to caustic soda. After causticizing, the combined Na_2S - NaOH solution is known as white liquor. This is settled and sometimes filtered through pressure filters, adjusted to the desired strength or concentration for cooking with weak black liquor, and stored for use in the pulping process.

The lime mud (calcium carbonate) obtained on settling this white liquor is washed and dewatered on rotary vacuum filters or centrifuges and burned in rotary or fluidized kilns to form quick lime. This is hydrated with green liquor in slakers for reintroduction to the recovery cycle.

Bleached Kraft

Prior to bleaching, the processing steps used in producing bleached kraft pulps are identical to those used in producing unbleached pulp with one exception.

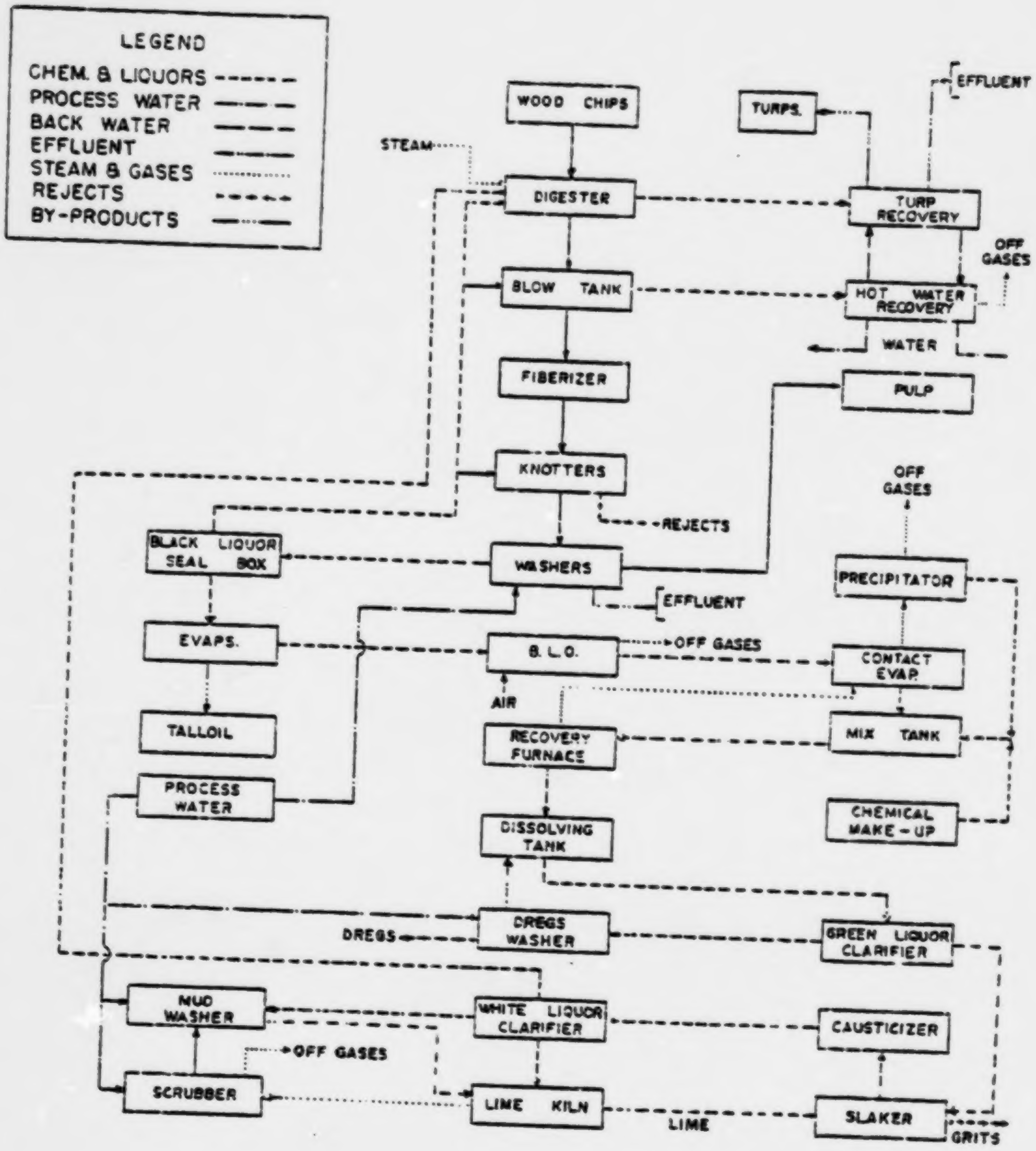
LEGEND
CHEM. & LIQUORS
PROCESS WATER
BACK WATER
EFFLUENT
STEAM & GASES
REJECTS
BY-PRODUCTS
WOOD CHIPS
TURPS.
EFFLUENT
STEAM
DIGESTER
TURP RECOVERY
OFF GASES
BLOW TANK
HOT WATER RECOVERY
WATER
FIBERIZER
PULP
KNOTTERS
REJECTS
OFF GASES
BLACK LIQUOR SEAL BOX
WASHERS
PRECIPITATOR
EFFLUENT
EVAPS.
B. L. O.
OFF GASES
CONTACT EVAP.
AIR
TALLOIL
RECOVERY FURNACE
MIX TANK
PROCESS WATER
CHEMICAL MAKE-UP
DISSOLVING TANK
DREGS
DREGS WASHER
GREEN LIQUOR CLARIFIER
MUD WASHER
WHITE LIQUOR CLARIFIER
CAUSTICIZER
OFF GASES
SCRUBBER
LIME KILN
LIME
SLAKER
GRITS

FIGURE 10 KRAFT PULPING PROCESS DIAGRAM (1)

In order to make kraft pulps more amenable to bleaching, the chips are sometimes steamed in the digester for a short period prior to the addition of the cooking liquor. This is called pre-hydrolysis and is a necessary adjunct to the production of dissolving pulps by the kraft process.

In this step, the chips are loaded into the digester which is then partially or totally filled with water and the whole mass is heated, usually by means of direct steam injection. As the temperature rises, wood acids are released and the pH drops rapidly from approximately 7.0 to 3.5. The acidic conditions degrade and solubilize hemicellulose molecules in the wood thus removing materials detrimental to the cooking process. After approximately two hours the acidic sugar-rich liquors are drained from the digester and the kraft liquor is introduced to start the cooking stage.

Neutral Sulfite Semi-Chemical (NSSC) Process

There are three main features of the NSSC process:

1. Impregnation of hardwood chips with cooking liquor
2. Cooking at high temperature
3. Mechanical fiberizing

While some mills buy the cooking chemical, it is more commonly prepared on the premises by burning sulfur and absorbing it in soda ash or ammonia, depending on which base is utilized. Newer mills employ continuous digesters although a large percentage of NSSC pulping still occurs in batch digesters which have been converted from other processes.

Maximum temperature is adjusted according to retention time in the digester. A short cook, 10 to 20 minutes at approximately 200°C. is characteristic of screw digesters. In vertical or rotating spherical digesters, a period of one to three hours at temperatures ranging from 160° to 175°C. is typical.

In some mills, the softened chips as they come from the digester are compressed in one or more stages of screw pressing. This facilitates maximum recovery of spent liquor and partial washing with minimum dilution. Either from this stage or directly from the digester they are sent to a disk mill for fiberizing. The chips then undergo vacuum or pressure washing, screening, and/or centrifugal cleaning. Digester relief and blow gases are condensed, and in some mills the condensate is used in pulp washing.

The pulp is conveyed to an agitated chest where it is diluted with white water from the paper mill to the desired consistency for feed to the secondary refiners servicing the papermaking operation. In making corrugating board, a small percentage of repulped waste paper is added to give the product desired characteristics.

The NSSC pulping process is illustrated in Figure 11.

Recovery or Burning of Cooking Chemicals--

Chemical recovery in the sodium base NSSC process is considerably more difficult than in the kraft process. The spent liquor is low in solids with a relatively high proportion of inorganic to organic constituents, and, thus, does not burn easily. Other factors which complicate recovery are a relatively high liquor viscosity and relatively low sodium to sulfur ratio.

Because of these factors many mills simply evaporate and burn the spent liquor without recovery. Evaporation is commonly accomplished in multiple-effect evaporators. The concentrated liquor is burned for disposal or recovery in a fluidized bed reactor or a specially designed furnace. In sodium base mills, the fluidized bed combustion units produce sodium sulfate which is suitable for use in kraft mill liquor systems.

Recovery of sodium base NSSC liquor alone is presently limited to a few large mills. Three have chemical recovery systems. Three others incinerate the liquor and two discharge to city sewers. For sodium base NSSC mills, the simplest recovery practice, which is called cross recovery, is to send the liquor to a nearby kraft recovery system.

No successful system has been developed for chemical recovery in ammonia base NSSC mills. In the two mills utilizing this base, the spent liquor is incinerated. The combustion products are gaseous with a negligible residue of inorganic ash.

Kraft-NSSC (Cross Recovery)

A substantial number of kraft pulp mills have an accessory sodium base neutral sulfite semi-chemical pulp mill. In most instances, these are kraft linerboard mills employing pine as a raw material from forest areas where appreciable hardwood species grow as well. These mixed hardwoods are harvested separately but simultaneously with the pine, cooked by the sodium base NSSC process, and manufactured into corrugating board. This product is compatible with linerboard since both are required to produce container board. Such combined pulp production also provides the simplest and most economic means for disposing of the sodium base NSSC spent liquor since it can be introduced into the kraft recovery system at one point or another to provide make-up chemicals to the kraft liquor, sodium and sulfur, to produce white liquor, the kraft cooking agent.

Kraft recovery systems can absorb spent liquor from an NSSC mill producing about one-third the tonnage of the kraft operation assuming that adequate evaporator capacity is provided to accept the NSSC brown liquor which is generally more dilute and lower in heat value than the kraft black liquor. One mill has been able to increase this ratio through a process employing crystalization of soda ash from the green liquor for use in preparing NSSC cooking liquor. This limitation has also been overcome by cooking the hardwood with green liquor, although the pulp produced has less

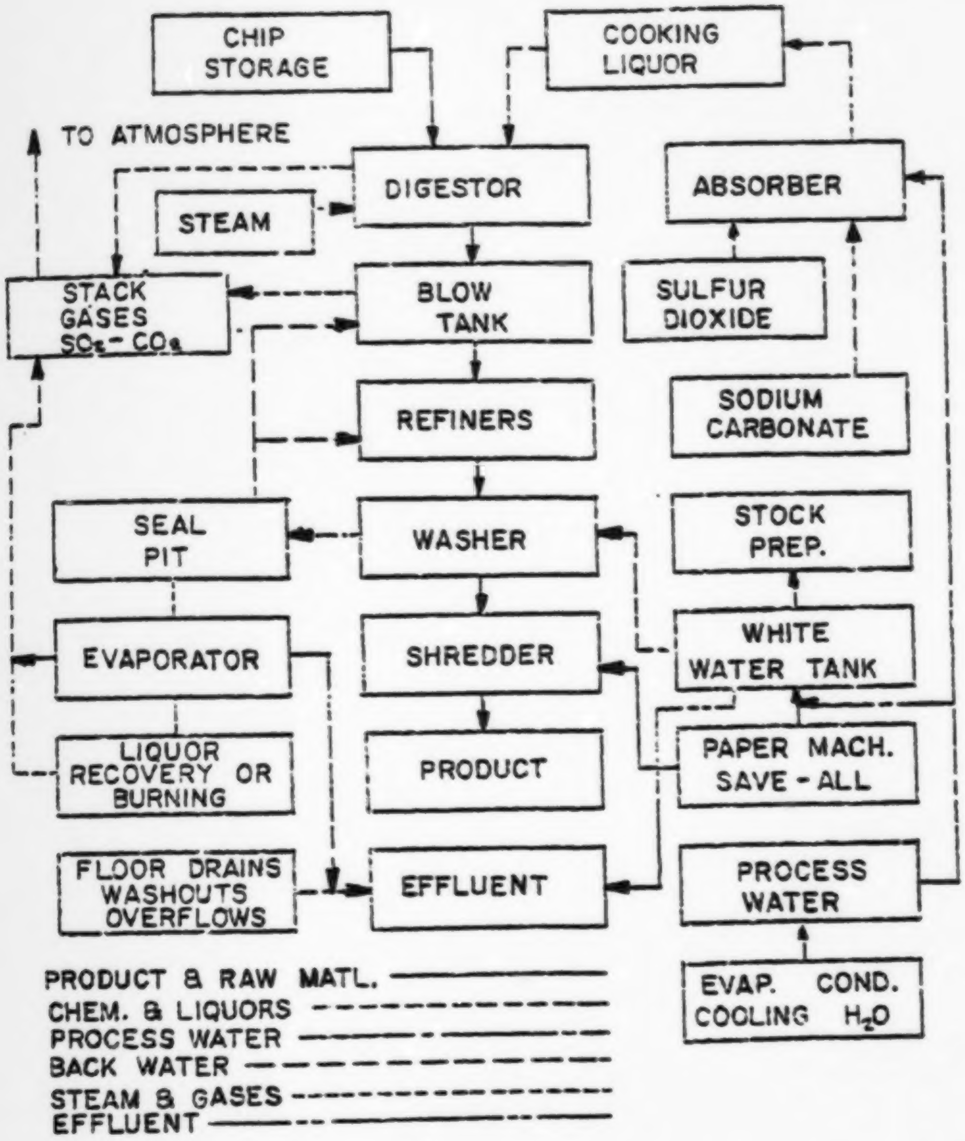
CHIP STORAGE
COOKING LIQUOR
TO ATMOSPHERE
DIGESTOR
ABSORBER
STEAM
STACK GASES $SO_2 - CO_2$
BLOW TANK
SULFUR DIOXIDE
REFINERS
SODIUM CARBONATE
SEAL PIT
WASHER
STOCK PREP.
EVAPORATOR
SHREDDER
WHITE WATER TANK
LIQUOR RECOVERY OR BURNING
PRODUCT
PAPER MACH. SAVE - ALL
FLOOR DRAINS WASHOUTS OVERFLOWS
EFFLUENT
PROCESS WATER
EVAP. COND. COOLING H_2O
PRODUCT & RAW MATL.
CHEM. & LIQUORS
PROCESS WATER
BACK WATER
STEAM & GASES
EFFLUENT

FIGURE 11 NEUTRAL SULFITE SEMI-CHEMICAL PULP PROCESS DIAGRAM (1)

desirable characteristics than NSSC. While limitations of 1:3 on the basis of NSSC to kraft pulping may appear severe, this is not usually the case because the large size of modern linerboard mills still allows an economic size NSSC operation.

Acid Sulfite

The acid sulfite process is used to make two distinctly different types of pulp: papermaking grades and dissolving grades. The basic process is the same for both, although there are significant differences in cooking temperatures, strength of chemical application, and bleaching practices. The following discussion of sulfite pulping is generally applicable to both. The major differences in its application to dissolving pulp are noted at the end of this discussion.

In the acid sulfite process, wood chips are cooked with solutions of the bisulfite of calcium, magnesium, ammonia, or sodium containing an excess of free sulfur dioxide. The cooking liquor is manufactured at the mill from purchased and recovered chemicals.

Sulfurous acid is prepared by absorbing sulfur dioxide in water. Sulfur dioxide is made at the mill by burning sulfur or is purchased in liquid form either of which is supplemented by that returned to process from the sulfur dioxide recovery system.

In calcium base mills, calcium is supplied either in the form of calcium carbonate or calcium oxide; the base is reacted with sulfurous acid and is not usually recovered from the spent liquor. In ammonia base mills, aqua ammonia is reacted with sulfurous acid. If the chemical is purchased in the anhydrous form, it is first put into solution. Ammonia, too, is not recovered. Magnesium oxide and caustic soda are purchased as make-up base for the magnesium and sodium base recovery systems which retain about 90 percent of the base in the system through recovery.

When ammonia, magnesium, or sodium base cooking is completed, the pulp is blown into a blow tank. It is then delivered to multi-stage vacuum washers on which countercurrent washing separates the spent liquor from the pulp. In the case of calcium base pulp and some ammonia base pulps, blow pits rather than tanks are generally employed where the pulp is washed by diffusion of wash water through the pulp mass. It is possible to recover 95 percent of the liquor solids by vacuum washing, but the limit is about 85 percent from displacement washing in blow pits. A 15-percent liquor concentration is obtainable by vacuum washing while the highest solids concentration attainable by blow-pit washing is about 10 percent. Off-gases are passed to an absorption system for recovery of their sulfur dioxide content. After washing, the pulp is diluted, screened, centrifugally cleaned, and deckered to the desired stock chest consistency for bleaching. A process diagram is presented in Figure 12.

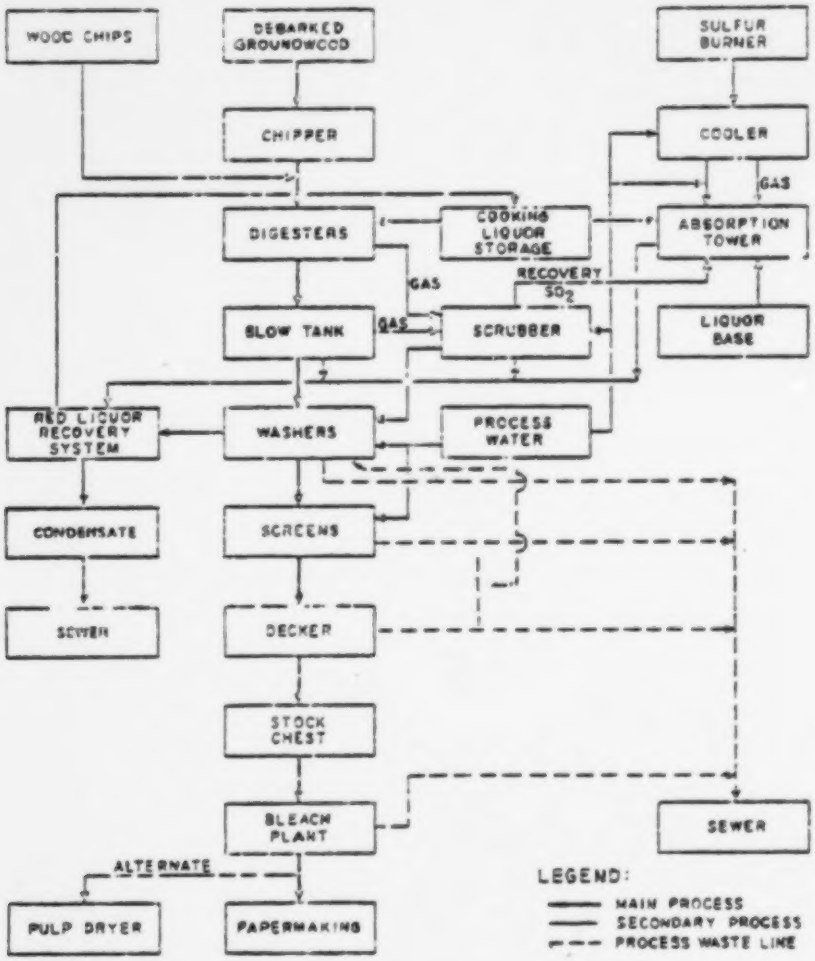
WOOD CHIPS
DEBARKED GROUNDWOOD
SULFUR BURNER
CHIPPER
COOLER
GAS
DIGESTERS
COOKING LIQUOR STORAGE
ABSORPTION TOWER
GAS
RECOVERY SO2
BLOW TANK
GAS
SCRUBBER
LIQUOR BASE
RED LIQUOR RECOVERY SYSTEM
WASHERS
PROCESS WATER
CONDENSATE
SCREENS
SEWER
DECKER
STOCK CHEST
BLEACH PLANT
SEWER
ALTERNATE
PULP DRYER
PAPERMAKING
LEGEND:
MAIN PROCESS
SECONDARY PROCESS
PROCESS WASTE LINE

FIGURE 12 SULFITE PULP MILL PROCESS FLOW DIAGRAM (2)

The weak red liquor separated from the pulp is evaporated in multiple effect long tube evaporators and recovery furnace contact units to a consistency of about 60 percent solids which is suitable for burning. Because of scaling problems, special evaporation units of the switching type are required for calcium base liquor. Also, forced feed evaporators must be used for ammonia base liquor because of its high viscosity.

In the magnesium base process, the ash produced on burning the liquor is magnesium oxide which is recovered in cyclones and returned to the liquor manufacturing section on the mill. The smelt obtained on burning sodium base liquor is solidified and redissolved under controlled conditions so that the soda ash and sodium sulfide present can be separated by differential solubility. The sodium sulfide is reacted with carbonic acid to form hydrogen sulfide which is burned to produce sulfur dioxide. The latter is reacted with the soda ash obtained from the smelt to form sodium bisulfite cooking liquor, and the carbon dioxide produced is employed in the sodium sulfide reaction. Ammonia base liquor is burned either in a typical recovery furnace or a fluidized bed unit and sulfur dioxide is stripped from the off-gases for use in the liquor preparation unit. A process flow diagram of a magnesium base sulfite recovery system is presented in Figure 13.

In the preparation of sulfite dissolving pulps, the wood is cooked at a higher than standard temperature. Cooking is continued until most of the lignin and part of the cellulose are dissolved whereas in papermaking pulps only a portion of the lignin is dissolved. The resulting spent liquor thus has a higher solids content and a much higher heat content when burned. In addition to screening to remove bark and wood particles after the pulp is washed, it is sent through special "side-hill" screens for thickening and to separate resinous materials.

Soda

The only major difference today between the soda and kraft processes and their recovery systems is that sulfur is present in kraft liquor and because of this black liquor oxidation is practiced at a number of kraft mills. All the recovery systems of both are designed to burn all the organic matter present in the black liquor rather than producing black ash as in the old soda process.

In the soda process wood chips are cooked in a solution of caustic soda containing 6.1 to 6.6 pounds of active alkali per cubic foot of liquor. When pulping is complete the contents of the digester are blown into a tank. Exhaust steam passes through a cyclone to remove entrained black liquor which is sent to the recovery plant. This steam and that contained in the relief gases is condensed in a heat exchanger used for heating process water before entering the atmosphere. Knots are removed from the pulp which is then washed on countercurrent drum washers generally in three stages. The pulp is then diluted, screened, and deckered to stock chest consistency.

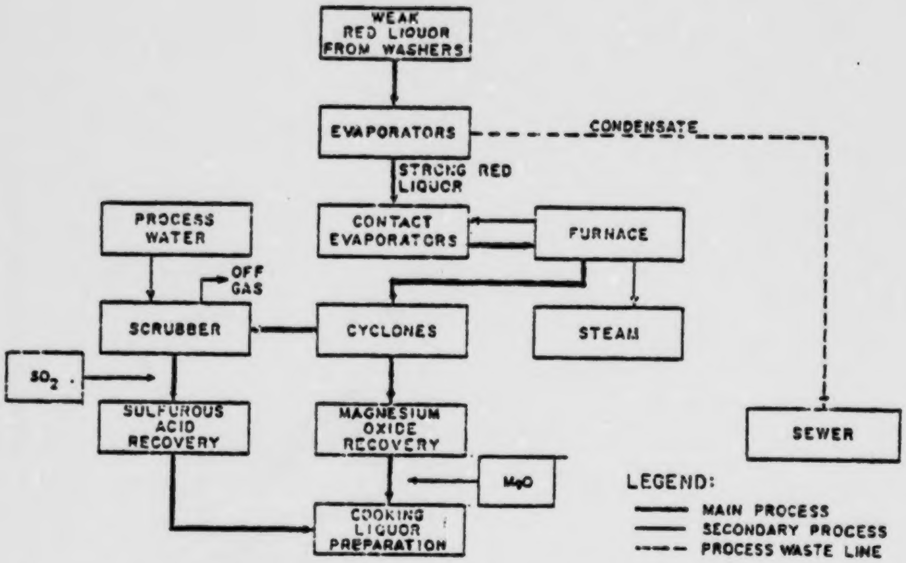
WEAK RED LIQUOR FROM WASHERS
EVAPORATORS
CONDENSATE
STRONG RED LIQUOR
CONTACT EVAPORATORS
FURNACE
PROCESS WATER
OFF GAS
SCRUBBER
CYCLONES
STEAM
SO_2
SULFUROUS ACID RECOVERY
MAGNESIUM OXIDE RECOVERY
SEWER
MgO
COOKING LIQUOR PREPARATION
LEGEND:
MAIN PROCESS
SECONDARY PROCESS
PROCESS WASTE LINE

FIGURE 13 MAGNESIUM BASE SULFITE RECOVERY SYSTEM PROCESS FLOW DIAGRAM (2)

The weak black liquor from the washers is concentrated to 40 percent solids content in long tube multiple effect evaporators and then to about 65 percent in a recovery furnace stack evaporator. The liquor is then burned in the recovery boiler. The molten ash, which consists almost entirely of sodium carbonate, is dissolved in weak wash water and the make-up chemical -- purchased and recovered soda ash -- is added to form green liquor. Also, the make-up chemical can be sodium hydroxide to the white liquor rather than sodium carbonate to the green liquor. The green liquor is clarified and causticized here with lime to convert the sodium carbonate to sodium hydroxide. The lime mud is settled and filtered from the solution which is now designated a white liquor. This is filtered through a pressure filter and stored for use in the digesters. Lime mud is dried and burned to calcium oxide which is slaked and used again for causticizing. The kiln is equipped with a venturi scrubber for dust collection which generally utilizes weak wash from the causticizing system. This is returned to the process carrying recovered lime and some soda.

The soda pulping process is identical to that of kraft pulping illustrated in Figure 10.

Mechanical Pulping

The energy used in producing conventional groundwood pulp -- stone or refiner -- is mechanical. Modified groundwood processes such as the cold soda (chemi-mechanical) and chemi-groundwood methods employ a mild chemical treatment ahead of mechanical fiberizing. The latter processes are considered here as mechanical pulping, however, because the chemical pretreatment is much milder and the mechanical action more drastic than is the case in semichemical pulping. In thermo-mechanical pulping, an off-shoot of refiner groundwood, the pretreatment is accomplished with heat and pressure. The cold soda and chemi-groundwood pulps are produced and used as a direct substitute for groundwood or as supplements to special furnishes. All mechanical pulps contain practically all of the wood substance and yields are generally 85 to 90 percent of the bone dry weight of the wood processed while semichemical pulps fall within the 60 to 80 percent yield range.

The type of wood economically available is a factor in selection of the groundwood process applied. Softwood does not necessarily require pretreatment and has thus been the traditional raw material of the stone groundwood process, and more recently of the refiner method. The high energy requirements of grinding untreated hardwood are overcome by the processes which incorporate pretreatment. Thus, their development made possible the use of large stands of hardwood for mechanical pulping. Sawmill wastes are another source of raw material for the mechanical processes which utilize wood chips.

Stone Groundwood--

In this process, billets are fed to the grinders by hand or automatically from a belt or chain conveyor and are forced hydraulically against the large rotating grindstone, specifically designed for the purpose. The pocket-type grinder is most common although the magazine, ring, and continuous or chain types are being installed in new mills. The grinding occurs in the presence of a large quantity of water which acts as both a coolant and a carrier to sluice the pulp from the body of the grinder. The pulp slurry is diluted to a consistency of from 0.6 to 0.8 percent and is passed through coarse and fine screens and a centricleaner to remove dirt and slivers. Over-sized rejects may be passed through a disc refiner and returned to the system ahead of the fine screens. The pulp slurry is then thickened on a decker to between 10 and 15 percent consistency and discharged to a stock chest for mill use, bleached, or thickened further for transport to other mills either in the form of wet lap at about 25-percent consistency or nodules containing 50 percent fiber. A diagram of the stone groundwood process is presented in Figure 14.

Refiner Groundwood--

The availability of saw mill chips as a low-cost wood source led to the development and exploitation of the refiner groundwood process which has the additional advantage of using less power than stone grinding. The chips are first washed and two stages of refining are generally employed in the pulp mill, the fiber receiving a third refining in the papermill. Disc type refiners are used which contain one fixed and one rotary disc between which the wood passes together with a stream of water. A double-disc type unit is used mainly for refining rejects. The pulp is discharged from the refiners at a consistency of about eight percent and move by a high-density pump to the secondary units. Here it is diluted to low consistency and subsequently fine screened and freed of dirt in centri-cleaners. Screen rejects are refined and returned to process ahead of the screens. After cleaning the pulp is handled in the same manner as stone groundwood as shown in the process flow diagram in Figure 15.

Cold Soda--

In the production of cold soda pulp, chips are soaked either at atmospheric pressure for two hours or under forced pressure for shorter periods of time in liquor containing 20 to 40 mg/l of caustic soda. The caustic expended varies from two to 10 percent of the weight of the wood depending on the wood species used and the pulp quality desired. The liquor is recycled after fortification. Subsequent separation of chips and liquor may be accomplished by gravity or screw or roll presses may be employed. The treated chips are then handled in a manner similar to that used in manufacturing refiner groundwood.

Chemi-Groundwood--

The liquor used in chemi-groundwood pulping contains from 60 to 180 mg/l of sodium sulfite buffered with one-sixth to a third that amount of soda ash. Hardwood billets are first impregnated with the liquor and then cooked for periods ranging from a half an hour to six hours at a maximum temperature of 135° to 150°C. (278-201°F.). This is followed by grinding on stones under operating conditions very similar to those of stone groundwood. This pulp is stronger than conventional groundwood.

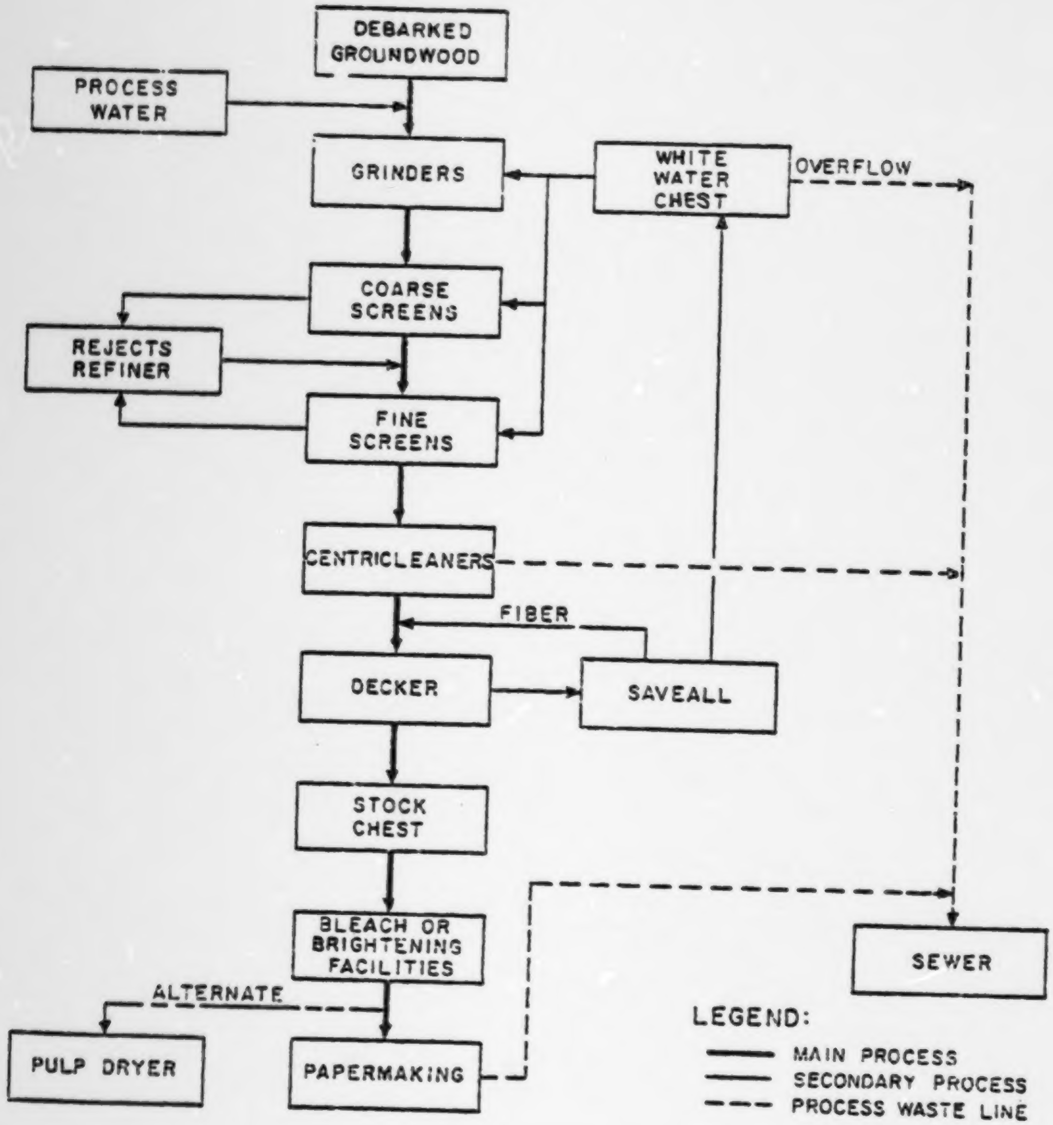
DEBARKED GROUNDWOOD
PROCESS WATER
GRINDERS
WHITE WATER CHEST
OVERFLOW
COARSE SCREENS
REJECTS REFINER
FINE SCREENS
CENTRICLEANERS
FIBER
DECKER
SAVEALL
STOCK CHEST
BLEACH OR BRIGHTENING FACILITIES
SEWER
ALTERNATE
PULP DRYER
PAPERMAKING
LEGEND:
MAIN PROCESS
SECONDARY PROCESS
PROCESS WASTE LINE

FIGURE 14 STONE GROUNDWOOD PULP MILL PROCESS FLOW DIAGRAM (2)

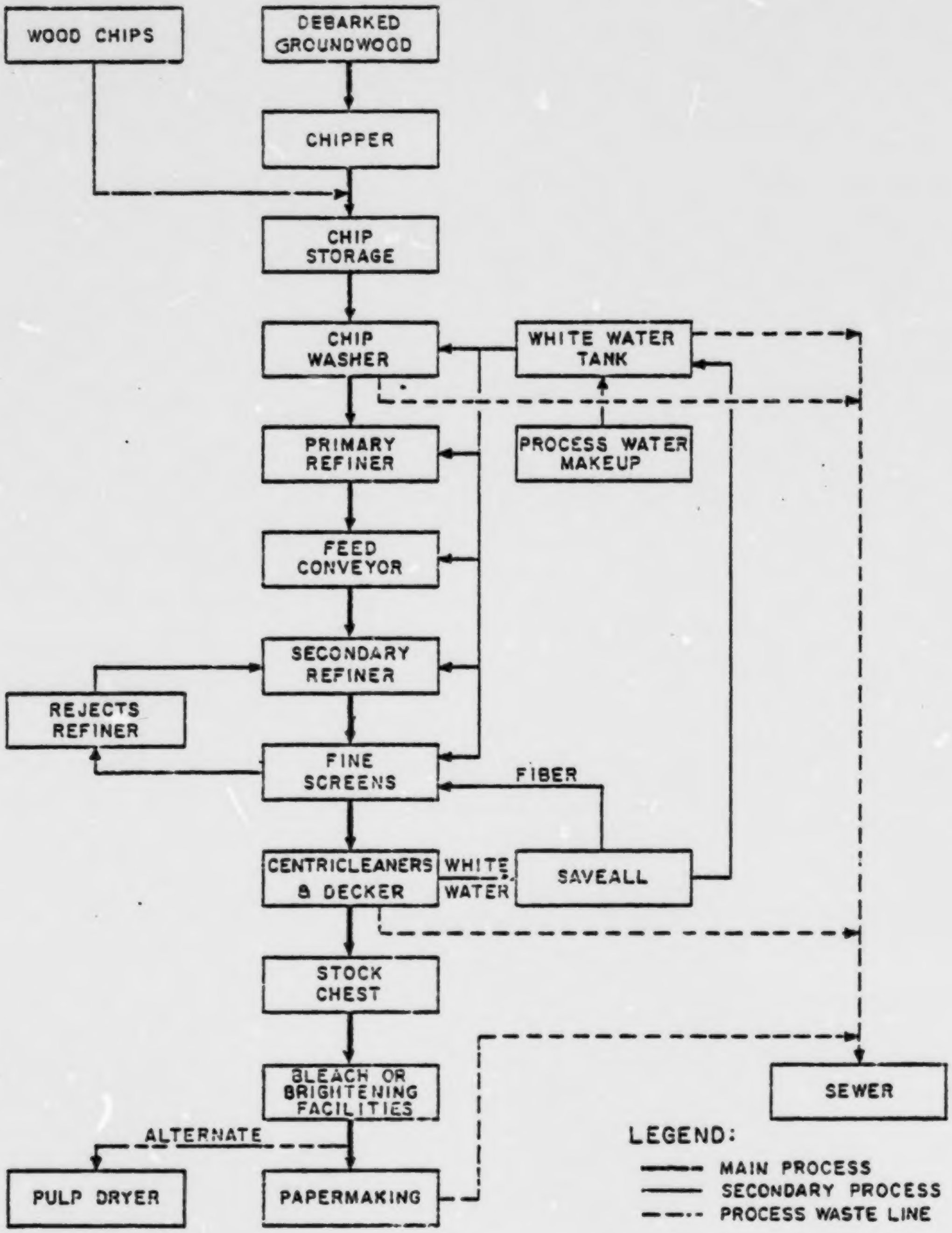
WOOD CHIPS
DEBARKED GROUNDWOOD
CHIPPER
CHIP STORAGE
CHIP WASHER
WHITE WATER TANK
PRIMARY REFINER
PROCESS WATER MAKEUP
FEED CONVEYOR
SECONDARY REFINER
REJECTS REFINER
FINE SCREENS
FIBER
CENTRICLEANERS & DECKER
WHITE WATER
SAVEALL
STOCK CHEST
BLEACH OR BRIGHTENING FACILITIES
SEWER
ALTERNATE
PULP DRYER
PAPERMAKING
LEGEND:
MAIN PROCESS
SECONDARY PROCESS
PROCESS WASTE LINE

FIGURE 15 REFINER GROUNDWOOD PULP MILL PROCESS FLOW DIAGRAM [(2)]

Deinked Pulp

A variety of waste papers are deinked to make several grades of pulp. Most waste paper used in this manner must be sorted and carefully classified since 1) not all papers are suitable for deinking; 2) certain types are desirable for some types of reclaimed pulps and are not suitable for others; and 3) papers which can be processed successfully by one process could be troublesome if mixed with papers requiring different treatment.

Waste paper is preferably sorted at its source (homes, offices, stores, factories, printers, or manufacturers of paper products such as boxes, envelopes, etc.); otherwise it must be sorted by the dealer, or at the mills. Sorting at the source is becoming more common today for two reasons. One, sorted waste papers bring higher prices both to the generator and the dealer than mixed bales. Second, sorting at the mill is an expensive hand operation.

Some mills are able to buy overruns of specific publications which are uniform in character. This makes for a successful operation since sorting is not required and the deinked product is more uniform.

High groundwood content papers are deinked for use in tissue or molded products, and for liner in board mills. These papers are not as suitable for fine or printing paper operations. Papers which contain plastics, latex, exotic inks, and other nondispersible materials cause difficulties in deinking, degrade the product, or generate troubles on the papermachine. Wet strength papers are given separate treatment because of their resin content.

Details of the deinking process used to produce pulp for fine papers depend upon the characteristics of the waste paper, but the process consists primarily of an alkaline cook to which dispersants, detergents, and solvents are added. The process is essentially a laundering operation in which the sizes, any coating binder, and the pigment vehicle in the ink are dissolved or dispersed and the ink pigment released, along with filler and coating agents such as clay, calcium carbonate, and titanium dioxide. Adhesives such as starch and glue are also dissolved and dispersed. The process is essentially the same in all mills except that somewhat different process units may be used from a variety of specific pieces of equipment.

The waste paper is generally cooked in a pulper at a consistency of between five and eight percent and a temperature ranging from 80° to 90°C. (180° to 210°F.). Cooking time is determined generally by examination of a sample from the pulper. During this step a trash boot and a ragger may be used to remove trash, rags, rope, wire, etc. The stock is then usually screened at about one to two percent consistency, after which it is ready for cleaning. This is accomplished by passing the stock at about 0.5 percent consistency through centricleaners and fine screens. Generally countercurrent washing is employed on washers of various types. Some mills employ flotation for separating the fiber from the undesirable materials and others use various kinds of deckering or thickening equipment. Fiber leaves the washers and is delivered to a stock chest at six to 15 percent.

Deinking practices in a tissue or molded pulp mill do not vary appreciably from the above. However, cooking temperatures for papers high in groundwood content are generally lower -- 38° to 71°C (100° to 160°F.) with a pH below 10. In addition, sodium peroxide is frequently adding to the cooking liquor since its bleaching action tends to prevent browning of the pulp.

A considerable shrinkage of the raw stock occurs in deinking because of the filler and coating materials washed from it along with large quantities of fiber fines when appreciable groundwood is present.

Newsprint is deinked by a proprietary process employing a special detergent. The pulp produced is suitable for conversion on high-speed newsprint paper machines with the addition of little, if any, long fiber stock and may not require bleaching. Shrinkage is reported to run around 15 percent.

In some nondeinking operations considerable quantities of books, envelope cuttings and flyleaf shavings, and similar unprinted scrap is repulped and washed free of fillers, adhesives, and sizing materials. Although ink removal is not involved, shrinkage and attendant sewer losses from such operations are similar to those from deinking.

At some paper mills relatively small amounts of selected kinds of waste paper are deinked from time to time for use in furnishes employed in the production of particular specialties. In some cases, almost the entire operation, including bleaching, is carried out in Hollander beaters. This may be the case also with the reclamation of fiber for use as liner in board mills.

Paperboard From Waste Paper

To convert waste paper to secondary fiber waste paper, sufficient water to provide desired consistency of four to six percent, and chemicals are charged at a controlled rate to a pulper along with steam. In this operation, the paper follows water circulating in a large open vat and is repeatedly exposed to rotating impeller blades. Over a period of time, it is ripped, shredded, and finally defibered. The pulper operation may be batch, continuous, or a combination of both. A junker is usually attached which, through centrifugal action, collects and removed extraneous solid materials and papers not suitable for use.

The stock is then passed to centrifugal cleaners, and finally to a thickener which may be preceded by pressure screens. Reject material is dewatered for disposal, and the stock is stored for use or goes directly to the refiners which serve the paper machines.

The removal of modern contaminants found in waste paper, including plastic containers, polystyrene packing materials, and other plastic coatings and laminants has required some refinements to the basic process. Some mills also have systems for dispersing the bituminous asphalt found in some reclaimed laminated kraft bags. This type system subjects the fiber to a heat and pressure environment in a press and digester.

The paper forming section of the board machine, or wet end, employed depends on the type of product made. Both fourdrinier and cylinder machines and some special devices as well are used. Variations and exceptions occur throughout the industry, although in general, a fourdrinier is used to make a single stock sheet and a cylinder machine a multi-ply sheet or heavy board. During recent years, cylinder machines have been replaced by variations of the dry-vat principle in order to produce a multi-stock sheet at higher speeds.

A process flow diagram of a typical paperboard from waste paper mill is shown in Figure 16.

BLEACHING METHODS

Bleaching of Chemical Pulp

The chemicals most commonly employed for bleaching chemical pulps are chlorine, calcium or sodium hypochlorite, and chlorine dioxide. Alkalies such as caustic soda and calcium hydroxide are used for extracting chlorinated reaction products from treated pulp. In some instances, hydrogen peroxide or sodium peroxide or peroxyacetic acid are used in the finishing stages of bleaching. Sulfur dioxide or sodium sulfite can be used as neutralizing and anti-chlor reagents and in some instances to stabilize pulp brightness. However, the chlorine compounds and alkalies are the most commonly applied chemicals.

Chlorine and caustic soda are either purchased in liquid form or, in rare cases, manufactured at the mill by electrolysis of sodium chloride. Hypochlorites are generally manufactured on site by treatment of milk of lime or caustic soda with chlorine. Strengths produced vary with intended use since this chemical is used not only for bleaching, but, in the case of dissolving pulps, to control rate of extraction of materials from the pulp and the ultimate viscosity of it.

Chlorine dioxide, because of its instability, is manufactured at mills which use it by one of four methods. These are the Mathieson process, a modification thereof, the R-2 process; and the Solvay process. They all employ sodium chlorate and sulfuric acid. Sulfur dioxide is also used in both the Mathieson processes, and sodium chloride is added in the modified Mathieson method and R-2 technique. Methanol is substituted for sulfur dioxide in the Solvay process.

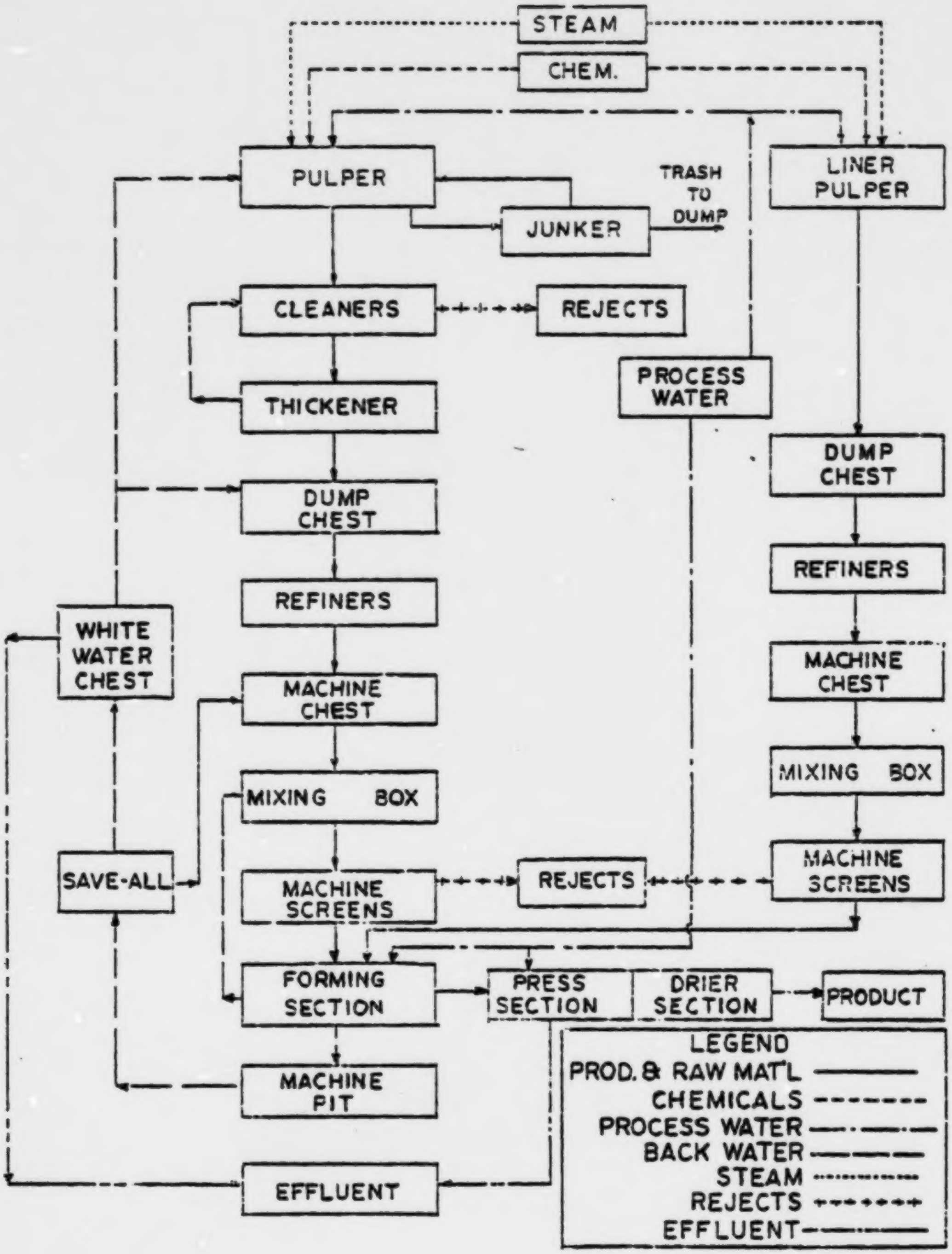
STEAM
CHEM.
PULPER
LINER PULPER
TRASH TO DUMP
JUNKER
CLEANERS
REJECTS
THICKENER
PROCESS WATER
DUMP CHEST
DUMP CHEST
REFINERS
REFINERS
WHITE WATER CHEST
MACHINE CHEST
MACHINE CHEST
MIXING BOX
MIXING BOX
SAVE-ALL
MACHINE SCREENS
REJECTS
MACHINE SCREENS
FORMING SECTION
PRESS SECTION
DRIER SECTION
PRODUCT
MACHINE PIT
EFFLUENT
LEGEND
PROD. & RAW MAT'L
CHEMICALS
PROCESS WATER
BACK WATER
STEAM
REJECTS
EFFLUENT

FIGURE 16 WASTE PAPER BOARD MILL PROCESS DIAGRAM (2)

Other bleaching chemicals are purchased in their common form and treating solutions are prepared according to process needs. These are employed in relatively small quantities as compared to the major bleaching agents.

Bleaching is ordinarily performed in a number of stages. This is done to preserve the strength of the pulp by avoiding excessively rigorous chemical treatment and to control consistency and temperature in accordance with the demands of the particular treatment applied. Each stage consists of a reaction tower in which the pulp is retained in contact with a particular chemical agent for the optimum period of time. It is then washed on vacuum washers or diffusers and discharged to the next stage. Consistency in the reactors generally ranges from 3.5 to 12 percent and temperatures range from ambient in the chlorination stage, to 60°C (140°F) in extraction stages, 35°C (95°F) in hypochlorite stages, and 82.2°C (180°F) in chlorine dioxide treatment.

The chemical concentrations employed depend upon the consistency, the temperature, the number of stages, the specific chemicals used, the species of wood from which the pulp was produced, and the degree to which it was cooked, as well as the quality of product desired. Three stages are generally used in semibleached kraft operations and for bleaching of sulfite paper grade pulps. Since kraft pulps are dark in color, particularly when made from softwoods, high-bright kraft pulps usually require more stages. Normally five are used although some mills employ six or more. Three stages may be used for low-brightness soda pulp and four stages for high brightness.

Table 67 shows the most common sequences used to bleach kraft pulp to various degrees of brightness.

For high bleach kraft pulp, the CEDED sequence appears to be favored. Ten mills report using it against 14 employing other sequences, most different from the other. CHHD is used by a few mills as a means of reducing color in the bleaching effluent. Mills which partially bleach kraft most commonly employ a CED sequence while a few either modify this procedure or add another hypochlorite stage. The CEH sequence is frequently used for bleaching paper grade sulfite pulps, although additional or other stages may be utilized by mills producing several different grades. CEH is also used by one mill for semi-bleached soda pulp; one soda mill employs CEHP for fully bleached pulp and another utilized CEHD.

A typical four stage kraft bleach plant is shown in Figure 17, and Figure 18 illustrates a three stage sulfite bleachery.

Bleaching of Dissolving Pulps

Dissolving pulps are always bleached, and, in addition, usually must undergo one or more additional reactions such as chemical purification, deresination, ash removal, etc. Most of these steps are combined in a complex bleaching and purification process.

TABLE 67. COMMON SEQUENCES USED TO BLEACH KRAFT PULP TO VARIOUS DEGREES OF BRIGHTNESS

Range of G.E. brightness	Bleaching* sequence
70 to 80	CEH CEHH
80 to 85	CHEH CEHEH CC/HEHH CED
85 to 92	CEHD CHED CEHDD CC/H ED/H CEDED CEDHED

Source: U.S. Environmental Protection Agency (1)

*Bleaching symbols

C - Chlorination
D - Chlorine dioxide
E - Alkaline extraction
H - Hypochlorite
/ - Successive addition of the respective agents without washing in between

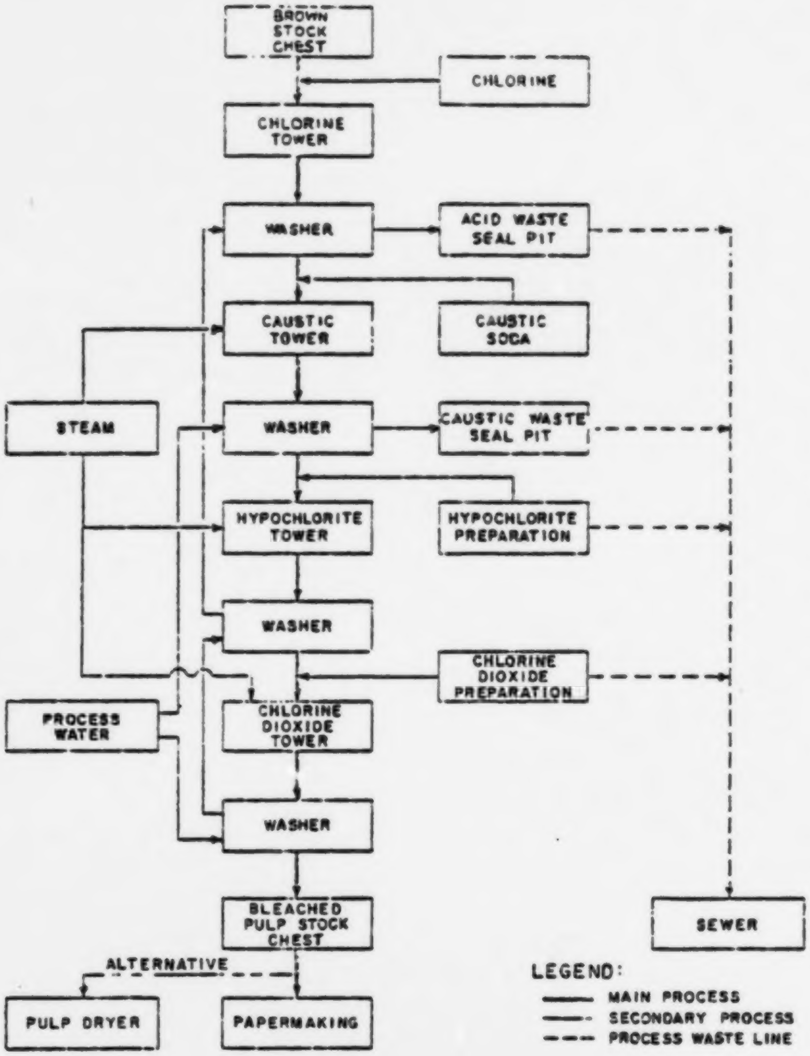
BROWN STOCK CHEST
CHLORINE
CHLORINE TOWER
WASHER
ACID WASTE SEAL PIT
CAUSTIC TOWER
CAUSTIC SODA
STEAM
WASHER
CAUSTIC WASTE SEAL PIT
HYPOCHLORITE TOWER
HYPOCHLORITE PREPARATION
WASHER
CHLORINE DIOXIDE PREPARATION
PROCESS WATER
CHLORINE DIOXIDE TOWER
WASHER
BLEACHED PULP STOCK CHEST
SEWER
ALTERNATIVE
PULP DRYER
PAPERMAKING
LEGEND:
MAIN PROCESS
SECONDARY PROCESS
PROCESS WASTE LINE

FIGURE 17 FOUR STAGE KRAFT PULP BLEACH PLANT PROCESS FLOW DIAGRAM (2)

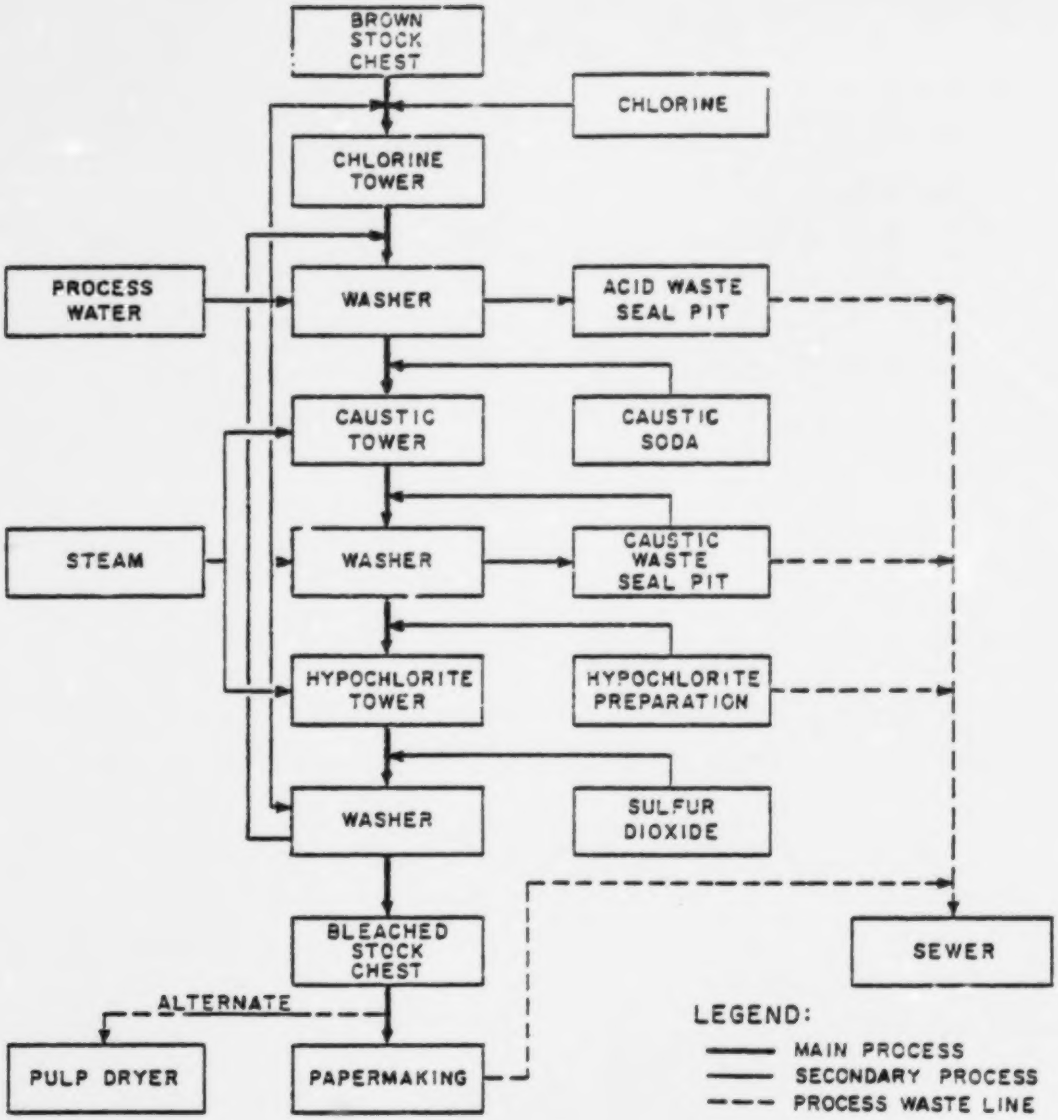
BROWN STOCK CHEST
CHLORINE
CHLORINE TOWER
PROCESS WATER
WASHER
ACID WASTE SEAL PIT
CAUSTIC TOWER
CAUSTIC SODA
STEAM
WASHER
CAUSTIC WASTE SEAL PIT
HYPOCHLORITE TOWER
HYPOCHLORITE PREPARATION
WASHER
SULFUR DIOXIDE
BLEACHED STOCK CHEST
SEWER
ALTERNATE
PULP DRYER
PAPERMAKING
LEGEND:
MAIN PROCESS
SECONDARY PROCESS
PROCESS WASTE LINE

FIGURE 18 THREE STAGE SULFITE PULP BLEACH PLANT PROCESS FLOW DIAGRAM (2)

The actual bleaching for both sulfite and prehydrolysis-kraft is accomplished by standard procedures as described in the previous section. CEHD is used by some sulfite dissolving mills, although others employ a five-stage process which may or may not include a chlorine dioxide stage. The use of this chemical, however, is indispensable for the production of dissolving grades from kraft pulp.

The purpose of the caustic extraction stage in bleaching dissolving sulfite pulps is somewhat different from its function in bleaching sulfite paper grade pulps. In the latter, this stage is utilized to remove partially bleached material solubilized in the chlorination stage. In the manufacture of dissolving pulp, the extraction stage is much more drastic in terms of caustic concentrations and degree of heat in order to dissolve a specific fraction of the cellulose itself which is not suited to the manufacture of rayon. Over 45 kg (100 lb) of caustic may be added per kkg (ton) of pulp and reaction temperatures exceed the boiling point while only about 14 kg (30 lb) of caustic under warm conditions are required for paper grade pulp. In dissolving pulp bleaching, this step dissolves approximately 10-16 percent of the pulp, depending on the grade of cellulose desired.

The final bleaching steps in sulfite dissolving also serve a different purpose from the last stage in bleaching paper pulp. In the latter case, the bleaching agent is usually used to achieve high brightness with minimum effect on the cellulose itself. In bleaching dissolving pulp, high brightness is only an incidental requirement and actual modification of the cellulose molecule itself is desired. Thus, the dissolving sequence usually ends with a relatively harsh bleaching agent such as sodium hypochlorite.

For kraft dissolving grades, the unbleached pulp is purified in the bleach plant to remove all traces of lignin and hemicellulose. This is done by means of a five to eight stage process, typically consisting of chlorination, caustic extraction, hypochlorite bleaching, chlorine dioxide bleaching, further caustic extraction followed by more chlorine dioxide and hypochlorite. Lignin is removed by chlorine and chlorine dioxide and hemicellulose by caustic extraction. The extreme hot alkaline extraction conditions designed for sulfite dissolving, described above, are not useful for the kraft dissolving process in which the alpha cellulose level is determined largely by cooking procedures.

Bleaching of Mechanical Pulp

Stone and Refiner Groundwood--

While these purely mechanical pulps have many desirable qualities for the manufacture of low-cost papers, they are not naturally sufficiently bright for the better grades. The brightness varies with the characteristics of the wood raw material. For example, northeastern spruce and balsam will generally produce a groundwood pulp in the brightness range of 57 to 65 units while the pulps from west coast species such as western hemlock range in the low 50's. Thus, bleaching is undertaken when necessary to satisfy the demands of various end products.

The most common bleaching agents used for stone and refiner groundwood are hydrosulfites and peroxides, and, in some cases, both are used sequentially as shown in Figure 19. Hydrosulfite systems can improve brightness by as much as eight to 12 standard brightness units in single stage operation and up to 15 to 20 units in a two stage operation with peroxide. Peroxide alone has capabilities in the range of eight to 12 or more units.

In peroxide bleaching, hydrogen peroxide is generally used although sodium peroxide is sometimes employed. A solution of from 0.5 to 1.5 percent hydrogen peroxide or its oxygen equivalent of sodium peroxide is applied to the pulp. Frequently a small amount of magnesium sulfate -- 0.24 to 0.48 mg/l (1 to 2 lb/500 gal) of bleach solution - is used for stabilization purposes. The pH of the pulp is first adjusted to 10.5 with caustic soda which requires from 1.0 to 3.0 percent NaOH. Sodium silicate or sulfamic acid sometimes replaces the caustic soda since they are capable of sequestering metallic ions which catalyze peroxide decomposition or discolor the product. Groundwood pulp is generally bleached with peroxide at between 38 and 49°C (100 to 120°F). Consistencies of bleaching range from four to 35 percent. The pulp is usually subsequently neutralized with sulfur dioxide to prevent reversion.

In some instances, refiner groundwood is subjected to refiner bleaching (e.g., a solution of peroxide is added to the disc refiner employed for fiberizing). The bleaching reaction thus begins while the pulp is refined and is subsequently completed after discharge by maintaining the pulp at discharge temperature, 77 to 93°C (170 to 200°F), for approximately 15 minutes.

Some mills mix nodulated (pressed and shredded) pulp with sodium silicate and hydrogen peroxide in tank cars or truck tankers utilizing the tankage in transit as a reaction vessel for the bleaching operation.

Peroxide solutions are prepared at the mill by batch or continuous methods, and may contain either hydrogen or sodium peroxide or both. Epsom salts, sodium silicate, sodium and/or hydrogen peroxide is replaced by caustic soda. In the case of a sodium peroxide solution, sulfuric acid is used to replace the hydrogen peroxide.

When sodium or zinc hydrosulfite is used to bleach or brighten groundwood pulp, the chemical is frequently added directly to the secondary refiner or grinder sinks, canals, or stock chests since heat is important to the reaction. From 0.2 to 2.0 percent of the chemical is used depending upon the species of wood from which the pulp was derived and desired brightness; a temperature of 49 to 50°C (120 to 130°F) is most desirable at a consistency of 15 percent or greater. Sodium hydrosulfite is now preferred because of zinc discharge limitations.

Hydrosulfite solutions are prepared from purchased hydrosulfite or from chemicals manufactured at the mill. In one method, zinc hydrosulfite is made by reacting zinc dust with aqueous sulfur dioxide. In another, the

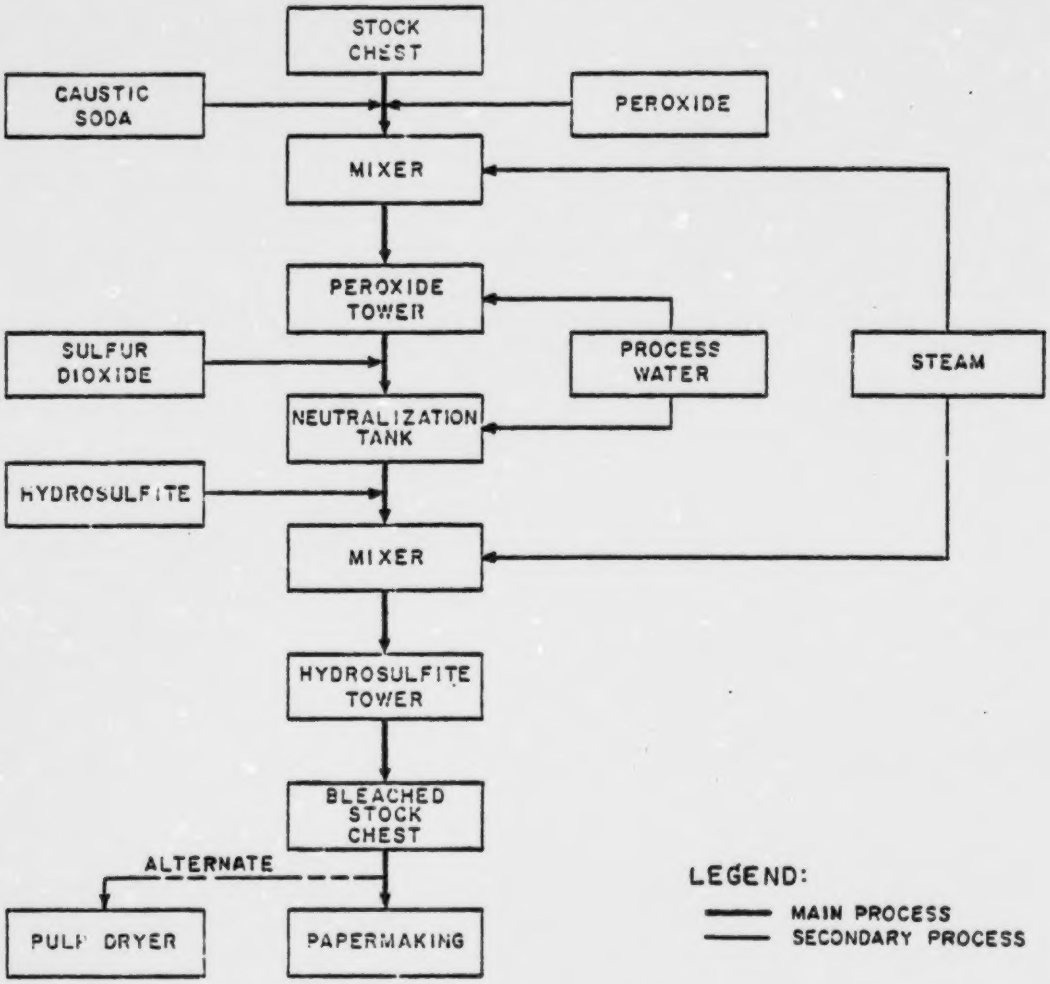
STOCK CHEST
CAUSTIC SODA
PEROXIDE
MIXER
PEROXIDE TOWER
SULFUR DIOXIDE
PROCESS WATER
STEAM
NEUTRALIZATION TANK
HYDROSULFITE
MIXER
HYDROSULFITE TOWER
BLEACHED STOCK CHEST
ALTERNATE
PULP DRYER
PAPERMAKING
LEGEND:
MAIN PROCESS
SECONDARY PROCESS

FIGURE 19 BRIGHTENING AND BLEACHING GROUNDWOOD AND COLD SODA PULPS PROCESS FLOW DIAGRAM (2)

zinc dust is mixed with pulp and the sulfur dioxide is introduced in aqueous solution or as a gas. Hydrosulfite can also be added dry at lower consistencies. Sodium and potassium borohydride, which also inhibits reversion following bleaching are sometimes used for brightening groundwood pulps, but, because of the chemical costs involved, the use of these chemicals has not become established practice in this country. The cost of peracetic acid has similarly precluded its use for groundwood bleaching.

Bleaching of Deinked Pulp

Deinked fibers consisting primarily of bleached chemical pulp are bleached in one stage with chlorine or calcium or sodium hypochlorite. From two to five percent of available chlorine is commonly used. Consistencies of the pulp bleached range from three to as high as 12 percent; tower type bleaching is used for the higher consistencies. When pulps containing considerable lignin are bleached after deinking, the three stage CED process commonly applied to kraft and sulfite pulps is employed. In this process, three percent of chlorine is applied to a dilute slurry of the pulp at ambient temperature. The pulp is then thickened and treated with caustic soda at 38°C (100°F) which is followed by washing and treatment with hypochlorite. A variety of equipment and variations of this process are in use. Pulps high in groundwood are bleached by the methods employed for groundwood alone and variations thereof employing caustic soda, peroxides, and hydrosulfites. Bleaching decreases the yield in the range of from 2.9 to five percent.

A process flow diagram of a deinking operation with single stage bleaching is presented in Figure 20.

PAPERMAKING

In stock preparation, pulp, either purchased or produced onsite, is resuspended in water to a consistency of four to six percent. The stock is mechanically treated in beaters or continuous refiners to brush or fray the individual fibers to obtain the necessary matting which produces the desired strength in the paper. This process also cuts the fibers to some extent. In cases where good formation is desired, such as fine papers, the stock is also pumped through a jordan which further cuts the fibers, with a minimum of brushing, to the necessary length. The amount of brushing and cutting varies with the type of pulp and the end product requirements. In a few cases, no mechanical treatment is needed.

Chemical additives may be added either before or after stock preparation. The most common additives are alum and rosin used for sizing, which prevents blotting of ink. Fillers such as clay, calcium carbonate, and titanium dioxide are added where opacity and brightness of the paper are important. A wide variety of other additives such as wet strength resins, dyestuffs, and starches may be used, depending on end-use requirements.

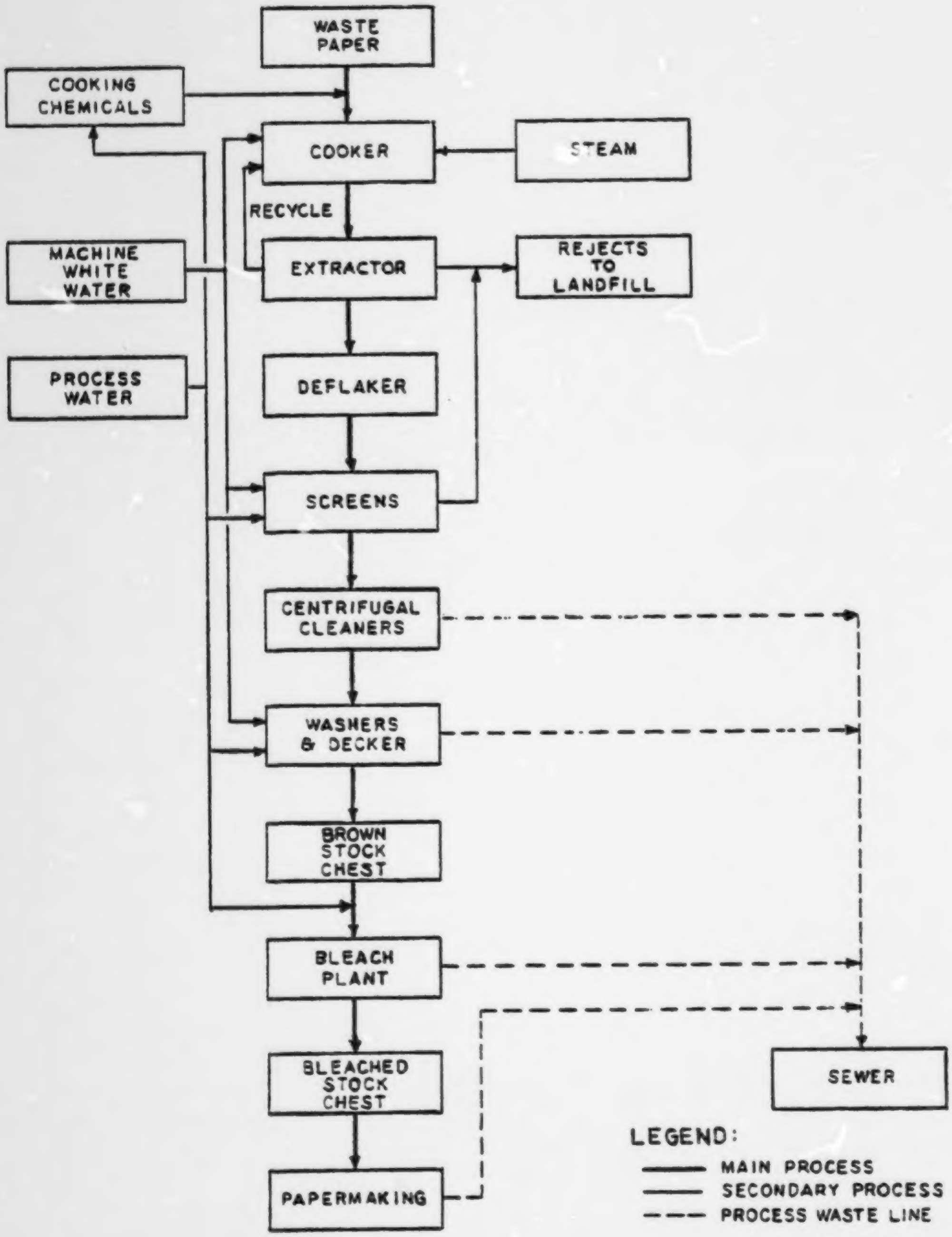
WASTE PAPER
COOKING CHEMICALS
COOKER
STEAM
RECYCLE
MACHINE WHITE WATER
EXTRACTOR
REJECTS TO LANDFILL
PROCESS WATER
DEFLAKER
SCREENS
CENTRIFUGAL CLEANERS
WASHERS & DECKER
BROWN STOCK CHEST
BLEACH PLANT
BLEACHED STOCK CHEST
PAPERMAKING
SEWER
LEGEND:
MAIN PROCESS
SECONDARY PROCESS
PROCESS WASTE LINE

FIGURE 20 DEINKING PLANT PROCESS FLOW DIAGRAM (2)

Either a fourdrinier or cylinder forming machine may be used to make paper/board. The primary operational difference between the two types is the flat sheet-forming surface of the fourdrinier and the cylindrical-shaped mold of the cylinder machine. The type of machine used has little bearing on the raw waste load.

In the fourdrinier operation, dilute pulp, about 0.5 percent consistency, flows from the headbox onto the endless wire screen where the sheet is formed and through which the water drains. A suction pick-up roll transfers the sheet from the wire to two or more presses which enhance density and smoothness and remove additional water. It then leaves the wet end of the machine at about 35 to 40 percent consistency and goes through dryers, heated hollow iron, or steel cylinders, in the dry end.

In the cylinder operation, a revolving wire-mesh cylinder rotates in a vat of dilute pulp picking up fibers and depositing them on a moving belt. The pressing and drying operations are the same as described above. The cylinder machine has the capacity to make multi-layered sheets, which accounts for its principal use in the manufacture of paperboard.

Because of its higher speed and greater versatility, the fourdrinier is in more common use than the cylinder machine. In either case, coatings may be applied in the dry end or on separate coating machines. After initial drying on the papermachine, the sheets may be treated in a size press, and then further dried on the machine. Calender stacks and breaker stacks may be employed to provide a smoother finish, either after drying or while the sheet is still partially wet.

A flow sheet of the fourdrinier operation is presented in Figure 21.

PAPERBOARD MANUFACTURING (3)

Paperboard may be made on both a cylinder and fourdrinier papermachine. The fourdrinier is used to make a single stock sheet while a cylinder machine is used to make a multi-ply board. Paperboard is often made from a waste paper although virgin fiber may be used wholly as a top and/or bottom liner to improve printability and appearance. Virgin fiber is also used where sanitary considerations are important. A typical cylinder machine process for converting waste paper to paperboard is described below.

Waste paper and water are added to the pulper at four to six percent solids. Steam and various chemicals are introduced to aid in fiberization of the waste stock. The waste paper is repeatedly exposed to rotating impeller blades which act to rip, shred, and finally disperse the waste paper.

A junker may be attached to the pulper to collect and remove extraneous solid materials not suitable for use. Such contaminants might include plastics of all types, water-insoluble adhesives, etc. The junker utilizes centrifugal force to accomplish removal of contaminants.

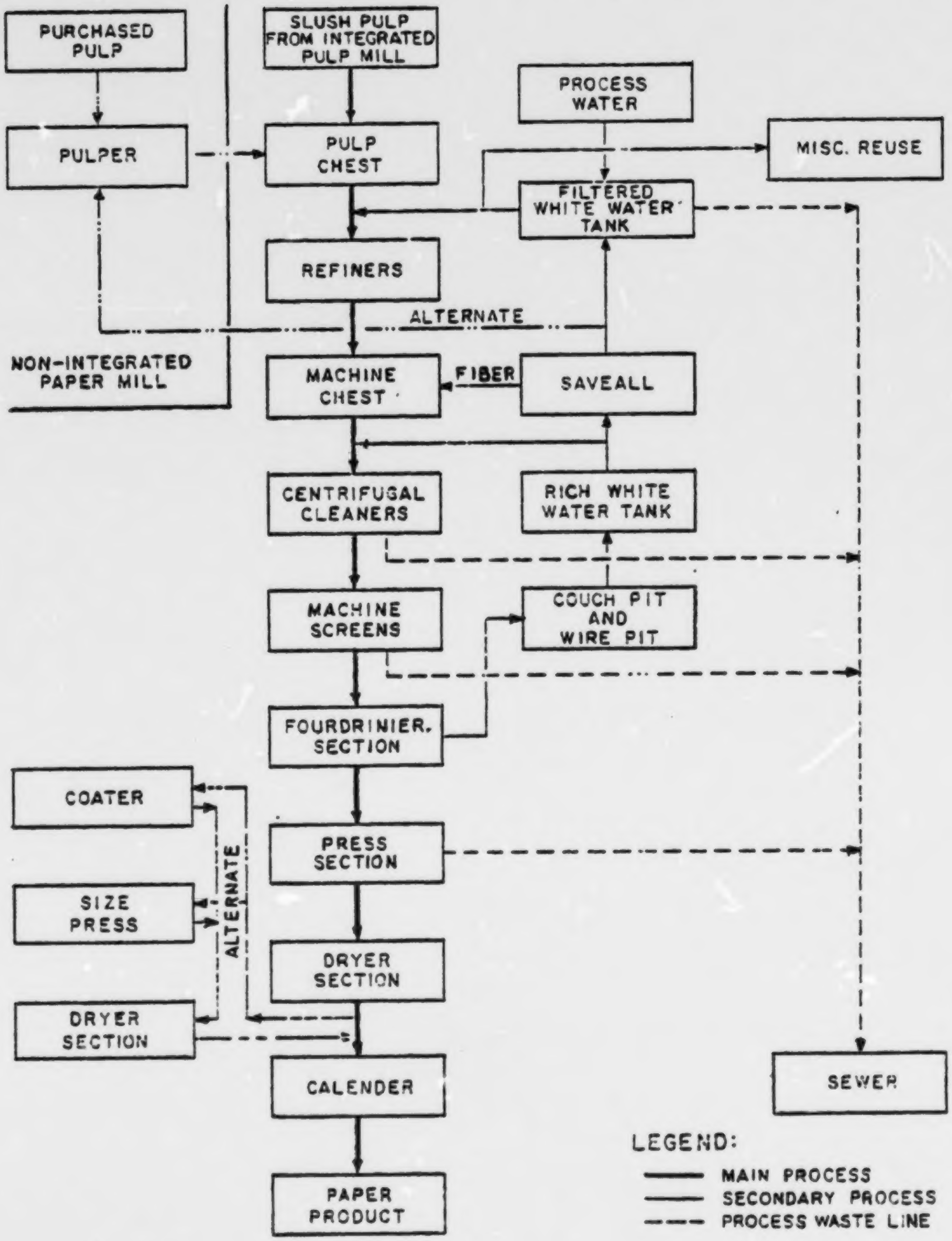
PURCHASED PULP
SLUSH PULP FROM INTEGRATED PULP MILL
PROCESS WATER
PULPER
PULP CHEST
MISC. REUSE
FILTERED WHITE WATER TANK
REFINERS
ALTERNATE
NON-INTEGRATED PAPER MILL
MACHINE CHEST
FIBER
SAVEALL
CENTRIFUGAL CLEANERS
RICH WHITE WATER TANK
MACHINE SCREENS
COUCH PIT AND WIRE PIT
FOURDRINIER. SECTION
COATER
PRESS SECTION
SIZE PRESS
ALTERNATE
DRYER SECTION
DRYER SECTION
CALENDER
SEWER
PAPER PRODUCT
LEGEND:
MAIN PROCESS
SECONDARY PROCESS
PROCESS WASTE LINE

FIGURE 21 PAPER MANUFACTURING PROCESS FLOW DIAGRAM (2)

The stock is passed through centrifugal cleaners or pressure screens to remove contaminants not eliminated in the junker, and is then processed through a thickener which increases the solids concentration of the pulp slurry. From the thickeners the pulp is sent to a dump chest for temporary storage prior to refiners.

The pulp is refined using a conical or disc refiner to impart the desired characteristics to the individual fibers. The pulp is then sent to the machine chest prior to paperboard manufacture where it is temporarily stored prior to final processing and papermaking.

The pulp is diluted to the desired consistency in a mixing box using some of the whitewater obtained from the cylinder machine forming unit. A machine screen, the final cleaning step, removes contaminants from the pulp.

The cylinder machine forming section actually is composed of a number of successive forming units which consist of wire covered cylinders partially immersed in the pulp slurry. Fibers are deposited on the wire while whitewater passes through the screen. The whitewater is collected and sent to a saveall. The paper so formed is removed from the top of the screen through the use of a felt. Papers or plies so formed are joined to produce a layered product which is pressed and dried to form paperboard.

The saveall collects the fiber fines and solid material from the whitewater. These solids are returned to the machine chest. The saveall effluent is reused in the pulper, or is sewered. After leaving the forming section, the board is pressed to reduce the moisture content of the board from approximately 75 percent to 60 percent. After pressing, the paperboard enters the dryer section of the machine. The drying section of the cylinder machine consists of a series of steam heated, rotating drums around which the continuous web of paperboard is conveyed. The purpose of this section is to dry the paperboard to approximately 6 percent moisture.

One optional process is a size press operation. The size press would be located within the dryer section. The general purpose of a size press is to surface treat the board. After the dryer section, the board may be processed through the calender stack. The purpose of the calender stack is to densify the board and smooth or polish its surface.

FABRICATED PAPER PRODUCTS (3)

Paper Coating and Glazing

Most paper coating and glazing operations of interest to these guidelines fall into three major subdivisions, including aqueous-base, solvent-base, and hot-melt coatings.

The constituents of aqueous-base coatings include the following:

Water - acts as the carrier for the dispersed or dissolved components.

Adhesives - provide a liquid vehicle to suspend the pigment during the coating process, to fill the voids between particles of pigment, and to bind them to each other and to the paper. Examples include such natural adhesives as animal glue, casein, and starch, as well as synthetic adhesives such as styrene-butadiene latex.

Pigments - provide the color and opacity. These include white, luminescent, colored, and metallic pigments.

Additives - impart various desired qualities. Some examples include foam controllers, lubricants, preservatives, flow modifiers, and insolubilizers.

Solvent-base coatings are in general, more expensive than aqueous-base coatings, but they offer the advantages of shorter drying times often affording greater production, better water and vapor resistance, and better mechanical properties. From the standpoint of controlling water use within a plant, they also can be readily recovered. The primary ingredients include:

Organic solvent - as with the aqueous-base coatings, these serve as carriers for the dispersed or dissolved components. Numerous organic solvents are utilized, but the largest numbers are esters, alcohols, ketones, and aliphatic and aromatic compounds.

Primary film formers - make up the principal binding portion of the film. These are polymers of high molecular weights. A few examples include nitrocellulose, cellulose acetate, ethyl cellulose, polyethylene, and cyclized rubber.

Secondary film formers - resins used to modify the properties of primary film formers.

Plasticizers - added to improve flexibility, reduce shrinkage, and lessen the tendency of paper to curl.

Pigments and dyes - used to produce desired color.

Fillers - used to extend pigment, increase solids, reduce tackiness, or reduce gloss.

Bronze powders - made from aluminum, copper, and copper-zinc alloys to produce metallic effects.

Hot-melt coatings are ones in which the solid materials that might be in solvent-base formulation are used, but made sufficiently fluid for coating machine application by heat rather than a solvent. The hot-melt coatings utilized include various resins and resinous materials (natural and synthetic), crystalline and amorphous waxes, cellulose derivatives and plasticizers.

Five unit processes are necessary for most coating operations.

1. Preparation and Blending of the Coating Mixture--

Coating mixtures are prepared in batch operations. The ingredients mentioned previously are mechanically mixed in a variety of vessels to prepare them for use.

2. Application of the Coating to the Paper--

A variety of techniques including dip, knife (blade), cast, roll, brush, air-knife, spray, print, extrusion, and strip are used to apply the coatings. However, all application techniques involve the application or transfer of coating to the substrate, metering to regulate coating weights and smoothing or leveling to obtain a plane surface. Aqueous-base coatings are generally applied with a brush coater or an air brush. Knife coaters and roll coaters are used for some applications. Solvent-base coatings, on the other hand, are generally applied either by one of several modifications of doctor knife or by means of some type of roll coater. Hot melts are applied by methods such as gravure, roller, sheet, cast, dip, and equilizer coating.

3. Drying of Paper Web--

Following the application of the coating, the paper web must be dried to enable final processing into rolls, skids, etc. The driers utilized must incorporate two essential processes - the transfer of heat to evaporate the carrier (water or solvent) and mass transfer of the evaporated liquid in vapor form. Production driers utilized are varied in nature and may accomplish heat transfer by convection, conduction, radiation, or a combination of the above.

4. Calendering or Finishing the Surface--

Immediately following the drying process, the paper web is given its final finishing. Often this includes the use of metal rolls to calender or "iron out" the surface of the paper to its desired texture, or the application of embossing rolls which impress a desired design.

5. Cutting or Rewinding, Inspecting, Packing, and Shipping--

Once coated, dried, and finished, the paper web is processed for delivery to the customer. Generally the final products is in the roll form, but sometimes may be cut into sheets, depending on the customer's specifications.

Envelopes

Paper is brought into the plant in roll form and cut into sheets, which are die cut in an envelope press. The envelopes are either printed or left plain, with window punching optional. The envelopes go through a folding and gluing operation, after which they are packaged and shipped.

Bags, Except Textile

Bag plant operations employ one of two major production processes. In one process, roll paper is printed, glued and subjected to shrink-over operations (plastic covering, packaging). In another process, rolls of paper are passed through a bag machine (open-mouth tuber which cuts to tube lengths), glued and sewn, followed by optional shrink-oven operations prior to shipment.

Die-Cut Paper and Paperboard and Cardboard

In making tabulating cards and special forms, roll paper is slit, printed (letterpress or offset) and die cut to form standards cards. They are then packaged (which requires some gluing) and shipped. Special forms require some assembling and gluing before they are packaged. To make single-ply business forms, roll paper is slit, printed, folded, or rewound, and packaged. For multiple plies, the forms are collated (carbon insertion and gluing) before they are packaged.

Pressed and Molded Pulp Goods

As previously mentioned, pressed and molded pulp goods include products molded from a wet pulp; these guidelines will cover only articles that are pressed from a dry paper stock. The products in this category are numerous but, in general, paper stock is printed (if necessary), pressed and cut, finished (lined, coated, etc.), and packaged.

Sanitary Paper Products

Different types of paper are purchased in the form of jumbo rolls. They are unwound, embossed (towels and napkins), and printed, if necessary. Paper stock for towels and bathroom tissue is perforated, rewound and packaged, which requires some gluing. Napkins, tissues, and industrial wipes are cut and folded after the printing operation and then packaged. For sanitary napkins and diapers, the process is essentially a gluing operation to adhere the fluffy pulp layer to the liners.

Stationary, Tablets, and Related Products

In making these items, roll paper is ruled (tablets) or printed (stationary), followed by cutting. All types of printing are utilized, including some photography. Covers are added, and the items are bound by stitching, gluing, or sewing. For plain stationary, roll paper is simply cut and packaged.

Folding Paperboard Boxes

In the folding carton production, large rolls of paperboard are printed then cut, creased, folded, glued and shipped. A varnish or coating may be put on after printing to protect the surface. Printing is usually rotogravure, offset or letter press. Although water-base inks are found in some folding carton plants, they are not common in this type of operation since they do not give as good a quality of color as oil-base inks. Gluing (usually water-base) in a folding carton plant generally refers to a side seam or cellophane window.

Set-up Paperboard Boxes

Rigid boxes are made from four basic materials: paperboard, corner stays, adhesive and covering material. First, flat sheets of boxboard are cut and scored to size. Individual blanks are separated from the sheet and the corners are cut out. Next, the sides of the blank are folded at right angles to the base to form the sides of a tray. The corners of the tray are stayed (sealed and reinforced) by adhering paper, cloth, or metal reinforcements to the corners. The same process is repeated for the cover. Decorative coverings (wrappers) are adhered last. Letterpress and offset are the processes most used in printing wraps.

Corrugated and Solid Fiber Boxes

Corrugated boxes are made by feeding roll paper into a corrugator to form corrugated sheets which are then creased, cut and slit according to box specifications. The blanks are then printed and sometimes coated. The flat box is folded and the side seam is either taped, stitched or glued. Some plants purchase the corrugated sheets rather than form them.

In the corrugating machine, the fluted medium is made on a die and adhered to a kraft liner at the single facer with an adhesive solution of cornstarch, caustic, and borax. The single-faced sheet is then processed through the double backer which applies the second facing, forming a single wall. This process can continue to form double and triple walls. Depending on its size, a corrugator can have several single facers.

Solid fiber boxes are made in a similar fashion, but a different based adhesive (usually polyvinyl acetate) is used and there is no fluting. The solid fiber sheets are finished in the same manner as the corrugated sheets. All types of printing are found in the industry.

Sanitary Food Containers

To make paper cups and plates, roll paper is slit to the desired width, moistened and printed, usually with water-base inks. The paper is then cut and formed into a plate, cup or container (cups and other containers require seam gluing). Plates, cold cups and some food containers go through different degrees of waxing, and are cooled with either air or contact water. The containers are then stacked, wrapped, packaged, and shipped.

Milk cartons and other food containers are made from a polyethylene coated paperboard, which is printed and cut into forms. There is no waxing since the board is already coated when purchased. The side seam is adhered by melting the polyethylene between the layers, so there is no gluing operation. The cartons are then stacked, packaged and shipped.

Fiber Cans, Tubes and Drums

To make these items, large rolls of stock paper are slit to the desired width of the product. An adhesive is then applied to one side of the paper as it is wound to the specified thickness and cut. The units can be left plain, painted, or silk screened, according to customer specifications. Cans and drums may be lined to accommodate the material they will be carrying. For certain items, metal covers and parts are assembled on the ends. Many plants have their own metal forming and finishing operations. These involve cutting fluids, oils, degreasers, varnishes, varnish removers, deburring solutions, and special cleaners and surface preparation solutions.

Blankbooks, Looseleaf Binders, and Devices

Stock paper is sheeted and ruled. The paper is cut to size and holes are punched for certain products. Covers are added and books are bound by either gluing, sewing, or wiring. The finished items are packaged and shipped. The binding process requires metal parts, which are usually made by the company. This includes the fabrication, finishing, and plating of metals.

GUM AND WOOD CHEMICALS MANUFACTURING (4)

This section includes generalized process flowsheets and descriptions for each of the product categories of the gum and wood chemicals industry.

Char and Charcoal Briquets

Char or charcoal is produced by the carbonation of wood, which is the thermal decomposition of the raw wood. The product yield and purity are a function of the kiln temperature. Above 270 C, exothermic reactions set in, and the process can be self-sustaining with the rate of carbonization normally controlled by limiting the air feed to the kiln. Higher temperature reactions produce a higher carbon content product but reduce the product yield. During the decomposition of the wood, distillates are formed and leave the kiln with the flue gases. The condensable distillates are collectively referred to as pyroligneous acid, which contains methanol, acetic acid, acetone, tars, oils, and water. These materials have steadily declined in economic importance because of cheaper methods of producing synthetic substitutes; therefore, most plants have discontinued recovery of the by-products from the pyroligneous acid. Instead, the distillate and other flue gases are fed to an afterburner for thermal destruction before the flue gases are exhausted to the atmosphere. The condensable distillates may also be recycled as fuel for the kiln or recycled in the vapor phase as a fuel supply supplement. The non-condensable gases contain CO_2, CO, CH_4, H_2 and some higher hydrocarbons. The composition of the gases depends on the distillation temperature.

A typical flow diagram for char and charcoal briquets manufacturing is illustrated in Figure 22. During this study, no facilities which recovered distillation by-products were known to exist in the United States. The kiln depicted in Figure 22 is loaded with a payloader. After the kiln is loaded the wood is set afire and allowed to burn under controlled conditions for approximately 72 hours. The air for oxidation is then cut off and water injected in the kiln for quenching. Approximately 18 hours is required for the material to cool down; afterward, it is removed by a payloader. Pine wood char is sold at this point in the process to fill specialized orders. Hardwood char is ground, then blended with starch binder and water for feed to the briqueting operation. The resulting briquets are dried and packaged in bags for sale.

The off gases from the furnaces contain compounds such as acetic acid, methanol, acetone, tars, and oils. These materials are presently oxidized in the afterburners. The natural gas fuel required for the afterburners is a significant operating cost. An alternative emission control is now under consideration, in which off gases from the furnace would be scrubbed to remove the condensables from the flue gases. The resulting scrubber liquor would be sent to a separator where the pyroligneous acid could be recovered. The water and soluble compounds would be reused in the scrubber system. The separated products can then be recovered for sale or used as an auxiliary fuel.

Gum Rosin and Turpentine

Figure 23 illustrates a process flow schematic for the manufacture of gum rosin and turpentine. The crude gum raw material is obtained by gum farmers who collect the gum from scarified longleaf and splash pine trees. The plant receives raw crude gum from the gum farmers in 435-lb. barrel shipments. These shipments contain some dirt, water, leaves, bark, and other miscellaneous trash. Gum is emptied into a vat by inverting the crude gum containers over a high-pressure steam jet. The melter liquifies the crude gum material, and recycled turpentine is added to reduce the viscosity. This mixture is filtered through a pressure filter and collected. The trash is periodically removed and hauled to a landfill. The filtered gum is then washed with water. Because iron and calcium causes gum rosin to discolor at high temperature, a small amount of oxalic acid may be added to the wash water to precipitate the iron and calcium as an insoluble acids and oxalite precipitate, and is then discharged for treatment. The prepared crude gum material is then distilled to separate the turpentine.

Non-contact shell-and-tube steam heating and sparging steam are used in the stills. Turpentine and water are distilled overhead and condensed with shell-and-tube condensers. The water is separated from the turpentine in the downstream receivers as shown in Figure 23. The turpentine product is

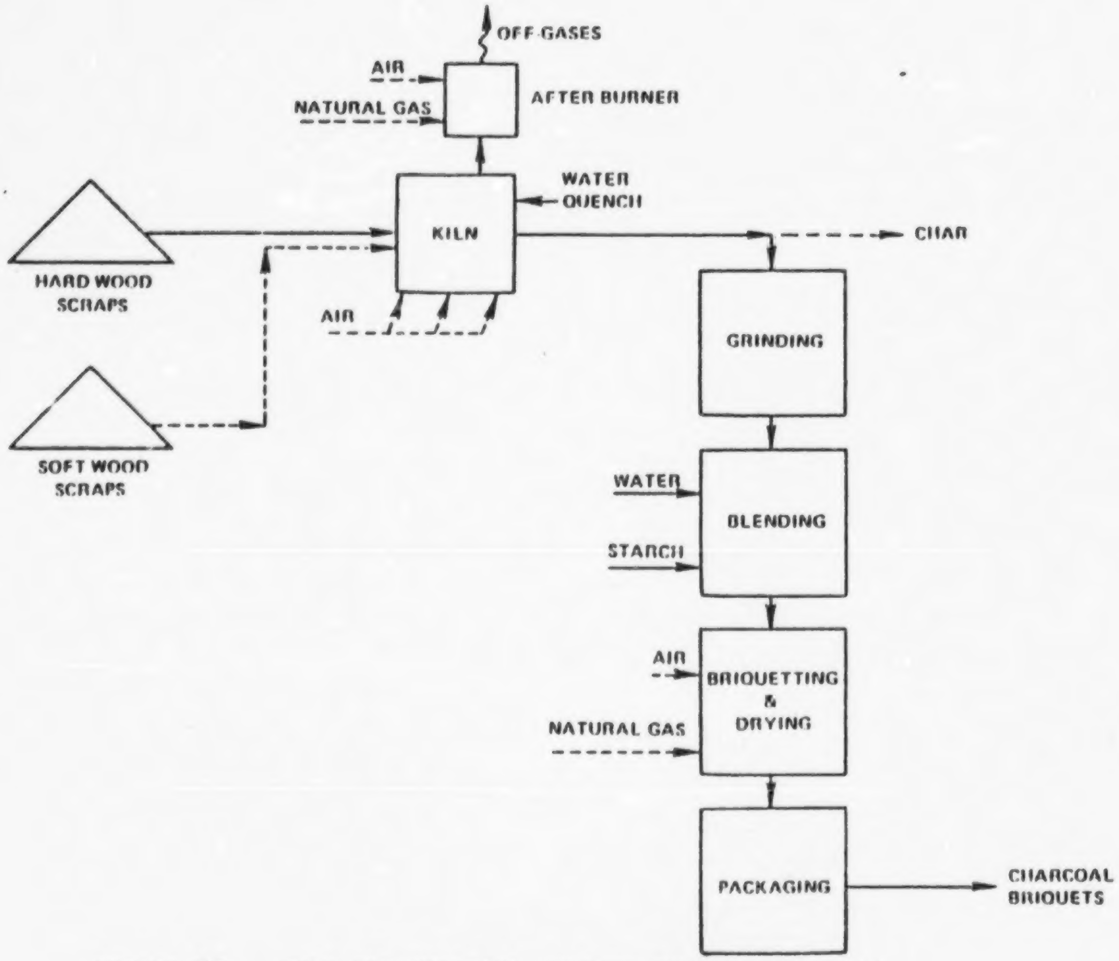
OFF GASES
AIR
NATURAL GAS
AFTER BURNER
WATER QUENCH
KILN
CHAR
HARD WOOD SCRAPS
AIR
GRINDING
SOFT WOOD SCRAPS
WATER
BLENDING
STARCH
AIR
BRIQUETTING & DRYING
NATURAL GAS
PACKAGING
CHARCOAL BRIQUETS

FIGURE 22 CHAR AND CHARCOAL BRIQUET MANUFACTURING (4)

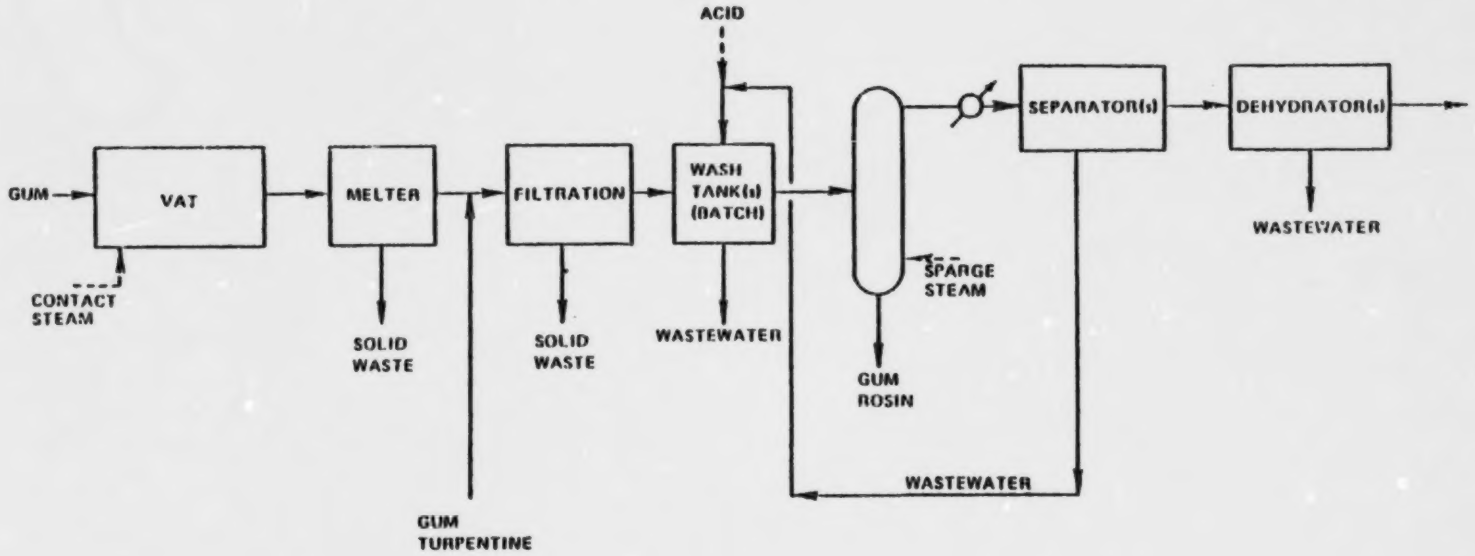
ACID
GUM
VAT
CONTACT STEAM
MELTER
SOLID WASTE
GUM TURPENTINE
FILTRATION
SOLID WASTE
WASH TANK(s) (BATCH)
WASTEWATER
SPARGE STEAM
GUM ROSIN
SEPARATOR(s)
WASTEWATER
DEHYDRATOR(s)
WASTEWATER

FIGURE 23 GUM ROSIN AND TURPENTINE PRODUCTION (4)

dried with a sodium chloride salt dehydrator, and the gum rosin is removed from the still after each batch distillation in a fluid state and packaged.

Wood Rosin, Turpentine, and Pine Oil

The raw material for this process is stumps obtained from the cut over pine forests of the southern United States. The stumps are uprooted by bulldozers and freighted to the extraction plant on railroad flat cars.

Figure 24 is a flow schematic diagram of the solvent extraction/steam distillation plant which was surveyed.

The pine stumps from 40- to 60-year old longleaf pine trees are brought into the plant. The stumps are placed on a conveyor and are washed with 1,000 gpm of water at a pressure of approximately 110 psi. The water and dirt flow to a settling pond where the dirt settles out and the water is recycled back to the washing operation. The accumulated dirt is periodically removed to landfill. Wood hogs, chippers, and shredders mechanically reduced the wood stumps in size in a sequence operation until they become chips approximately 2 inches in length and 1/16 inch thick. These chips are placed into intermediate storage. The wood chips are fed to a battery of retort extractors. The extraction process is accomplished in sequential steps as follows:

1. Water is removed from the chips by azeotrophic distillation with a water-immiscible solvent.

2. The resinous material is extracted from the wood chips with a water-immiscible solvent.

3. Residual solvent is removed from the spent wood chips by steaming.

After the final step, the spent wood chips are removed from the retort and sent to the boilers as fuel. During Steps 1 and 3, the steam solvent azeotrope from the retorts proceeds to an entrainment separator. Any entrained wood fines coming from the retorts are removed in the entrainment separator and are used in the furnace as fuel. The vapors from the entrainment separator are condensed and proceed to one or more separators where the solvent-water mixture separates. The solvent is recycled for use in the retorts.

The extract liquor leaving the retorts during Step 2 is placed into intermediate storage tanks prior to further processing. The contents of these tanks are sent to a distillation column to separate the solvent from the products. The column is operated under vacuum conditions maintained by a steam-jet ejector. The overhead from the column is condensed and enters a separator where a condensed solvent is removed and recycled to the retorts. The vapor phase from the separator, along with the steam from the ejector, is condensed in a shell-and-tube exchanger and enters a separator. Here the remaining solvent and the condensed steam from the ejector are separated. The solvent is sent to recycle and water to treatment.

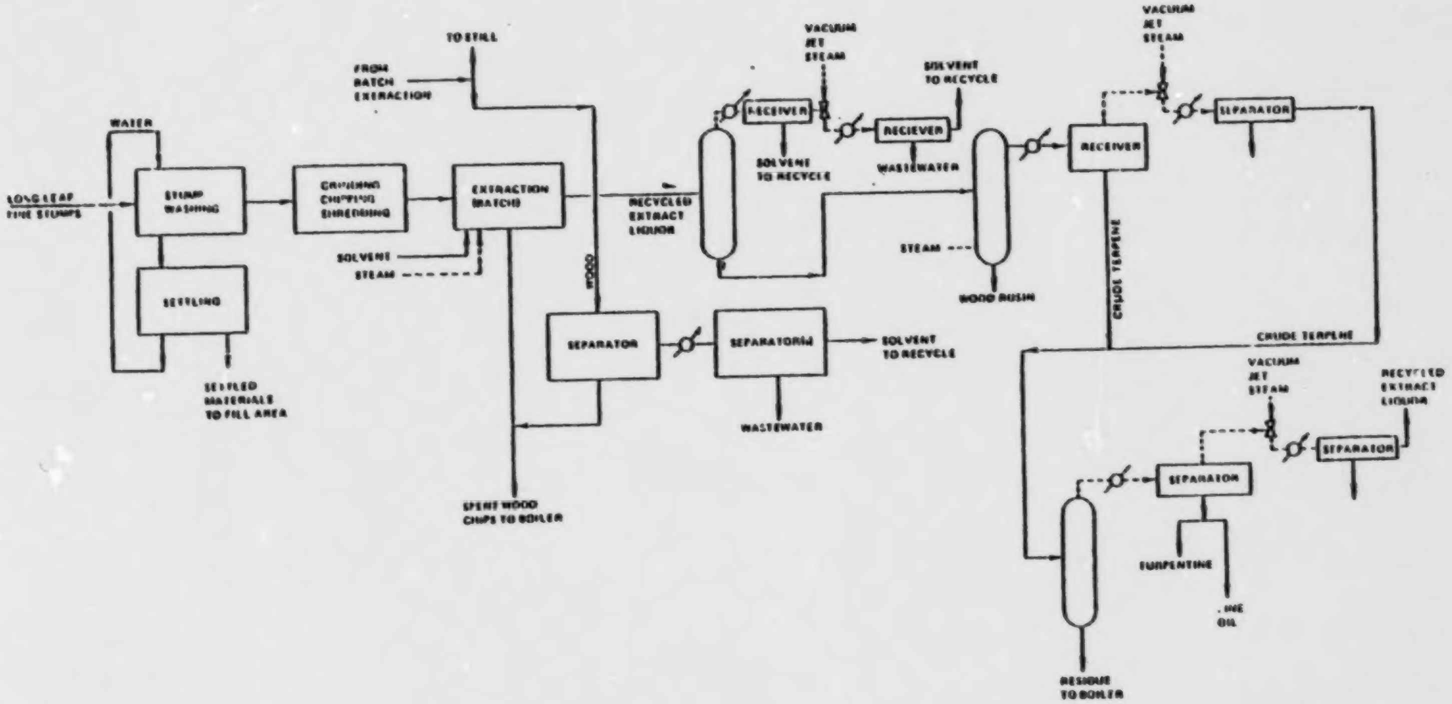
LONGLEAF PINE STUMPS
WATER
STUMP WASHING
SETTLING
SETTLED MATERIALS TO FILL AREA
GRINDING CHIPPING SHREDDING
SOLVENT
STEAM
EXTRACTION BATCH
FROM BATCH EXTRACTION
TO STILL
WOOD
SEPARATOR
SPENT WOOD CHIPS TO BOILER
RECYCLED EXTRACT LIQUOR
RECEIVER
VACUUM JET STEAM
SOLVENT TO RECYCLE
RECIEVER
SOLVENT TO RECYCLE
WASTEWATER
STEAM
WOOD ROSIN
SEPARATOR
SOLVENT TO RECYCLE
WASTEWATER
RECEIVER
VACUUM JET STEAM
SEPARATOR
CRUDE TERPENE
CRUDE TERPENE
VACUUM JET STEAM
RECYCLED EXTRACT LIQUOR
SEPARATOR
SEPARATOR
TURPENTINE
PINE OIL
RESIDUE TO BOILER

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FIGURE 24 WOOD ROSIN, PINE OIL, TURPENTINE PRODUCTION VIA SOLVENT EXTRACTION (4)

The bottoms stream from the first distillation column enters a second distillation column, also operated under vacuum, as shown in Figure 16. Steam is introduced into the bottom of the tower to strip off the volatile compounds. This overhead stream enters a condenser and separator. A portion of the condensed liquor phase is refluxed back to the distillation column, while most of it is stored as crude terpene for further processing. The steam from the vacuum ejector and the vapor phase from the separator are condensed in a shell-and-tube exchanger and then sent to a separator. The non-aqueous phase from the separator is stored as crude terpene while the aqueous phase is removed as wastewater. The bottom stream from this second distillation column is the finished wood rosin product.

The crude terpene which has been removed in the second distillation column, is stored until a sufficient quantity has been accumulated, then this material is processed in a batch distillation column. The distillation column is charged with the crude terpene material, the overhead vapors are condensed in a shell-and-tube exchanger, and the condensed material enters a separator. The turpentine and pine oil products are removed from this separator while the vapors and the steam from the steam ejector enter a second shell-and-tube exchanger and proceed to a separator. The nonaqueous phase from the separator is recycled to the extract liquor storage while the aqueous phase is sent to wastewater treatment. The bottom from this batch distillation column is a residue containing high-boiling point materials, best described as pitch. This residue is used for fuel.

Tall Oil Rosin, Fatty Acids, and Pitch

Technology for the production of high-purity tall oil rosin and fatty acids is relatively recent compared to the age of the wood and gum rosin manufacture. The first commercial fractionation process was completed in 1949 by Arizona Chemical. The Arizona plant employed partial vacuum distillation techniques in the petroleum refinishing industry and adapted to protect the integrity of tall oil's heat-sensitive constituents.

Modern fractionation techniques yield fatty acids which contain less than two percent rosin and rosins which contain less than three percent fatty acids. Distillation techniques employed prior to the current fractionation technology employed steam distillation which produced rosin and fatty acid products with relatively high cross-product contamination.

The plant surveyed during this study employed modern fractionation distillation techniques. A schematic process flow diagram of this crude tall oil (CTO) fractionation process is presented in Figure 25. The plant fractionates CTO to produce approximately 20 percent pitch, 49 percent fatty acids, and 31 percent rosin. In addition, part of the plant's pitch and rosin production is used captively for the production of paper sizes.

The CTO is treated with dilute sulfuric acid to remove some residual lignins plus mercaptans, disulfides, and color materials. Acid wash water goes to the process sewer. The CTO then proceeds to the fractionation

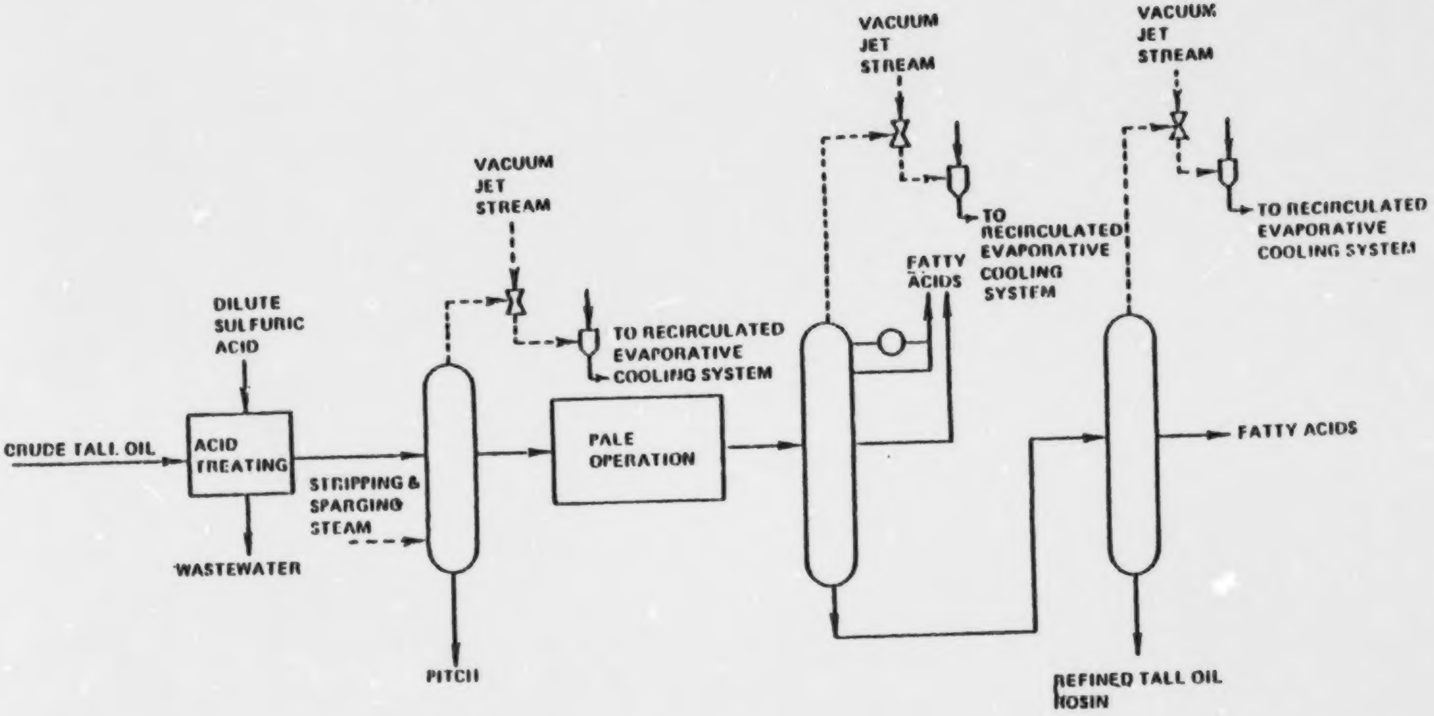
VACUUM JET STREAM
VACUUM JET STREAM
VACUUM JET STREAM
TO RECIRCULATED EVAPORATIVE COOLING SYSTEM
TO RECIRCULATED EVAPORATIVE COOLING SYSTEM
TO RECIRCULATED EVAPORATIVE COOLING SYSTEM
DILUTE SULFURIC ACID
FATTY ACIDS
CRUDE TALL OIL
ACID TREATING
PALE OPERATION
FATTY ACIDS
STRIPPING & SPARGING STEAM
WASTEWATER
PITCH
REFINED TALL OIL ROSIN

FIGURE 25 CRUDE TALL OIL FRACTIONATION AND REFINING [4]

process. In the first fractionation column, the pitch is removed from the bottoms and is either sold, saponified for production of size, or burned in boilers to recover its fuel value. The remaining fraction of the tall oil (rosin and fatty acid) then proceeds to the pale plant, where the quality of the raw material is improved through the removal of unwanted materials such as color bodies. The second column in Figure 25 separates low-boiling point fatty acid material while the third column completes the separation of fatty and rosin acids.

Barometric contact condensers are employed to condense the vacuum-jet steam. The recirculated barometric contact water is cooled by a holding reservoir, while light-separable organics are removed by means of an induced draft cooling tower. Once-through cooling water is used in non-contact column reflux and product heat exchangers.

Essential Oils

Figure 26 is a process flow schematic diagram for steam distillation of cedarwood oil from scrap wood fines of red cedar.

Raw dry dust from the planing mill and raw grain dust from the sawmill are mixed to obtain the desired blend and then fed pneumatically to mechanical cyclone separators which are located on top of the retorts. After loading, the extraction of oil of cedarwood is accomplished by injecting steam directly into the retort as shown in Figure 26. The steam diffuses through the cedarwood dust, extracting the oil of cedarwood, exits through the top of the retort, and is condensed to an oil/water mixture.

Following the steam extraction, the spent sawdust is allowed to cool for approximately two hours. The spent sawdust is then conveyed to storage from where it is eventually fed as fuel to the steam generators.

The primary product is a crude light oil which is separated by two oil/water separators immediately downstream of the condensers. The light oil is removed and mixed with clay. The clay lightens the product by removing color bodies and stabilizes the color of the product by inhibiting further oxidation. The clay/oil slurry is filtered through plate and frame pressure presses and the spent clay filter material is hauled to landfill for final disposal. The lightened oil product proceeds to bulk storage, blending, and is finally drummed for shipment.

The water phase, which is separated in the stillwells, contains a heavy red crude oil. This material is separated from the water phase in three settling tanks in series. The heavy red oil is periodically removed and drummed for sale as a co-product, while the underflow, or remaining water phase, is discharged as wastewater.

The cedarwood oil process has been described and the operation is representative of this category for production of other essential oil products.

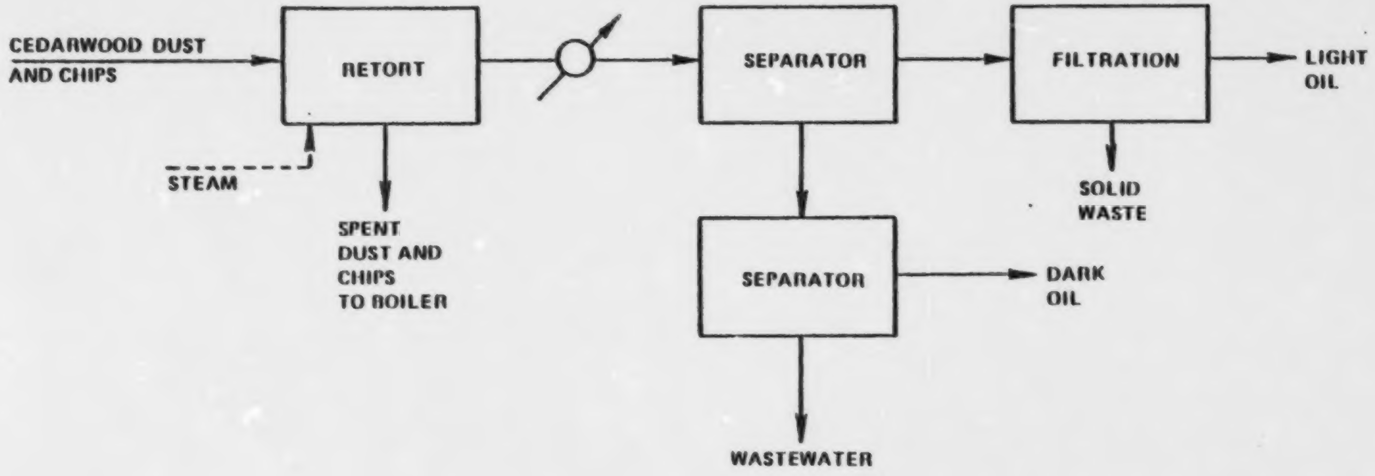
CEDARWOOD DUST
AND CHIPS
RETORT
STEAM
SPENT
DUST AND
CHIPS
TO BOILER
SEPARATOR
SEPARATOR
WASTEWATER
FILTRATION
SOLID
WASTE
LIGHT
OIL
DARK
OIL

FIGURE 26 DISTILLATION AND REFINING OF ESSENTIAL OILS[4]

Rosin Derivatives

Most of the rosins produced in the United States are actually rosin derivatives. Prior to the development of rosin derivatives, rosin was used in the production of printing inks, linoleum, varnishes, electrical insulation, foundry core oils, leather, matches, adhesives, masonry, and solder fluxes. Rosins have some undesirable properties which include a tendency to crystallize from the solvents employed, oxidation of the unsaturated chemical bonds, and reaction with heavy metal salts. Rosin derivative manufacturing has modified the various rosins to eliminate these undesirable properties and to enhance their application in the foregoing areas of application and other new areas.

It should be noted that there are many rosin-derivative manufacturing processes including isomerization, oxidation, hydrogenation, dehydrogenation, polymerization, salt formation, and decarboxylation.

Process operating conditions in the reaction kettle are dependent on many variables, such as product specification and raw materials. For example, if a simple ester is produced from stump wood rosin (ww grade) and U.S.P. glycerin, and the esterification reaction takes place under high-temperature vacuum conditions. During the process, a steam sparge (lasting approximately two to three hours) is used to remove excess water of esterification, which allows completion of the reaction and removes fatty acid impurities for compliance with product specifications. The condensable impurities are condensed in a non-contact condenser on the vacuum leg and stored in a receiver. Non-condensables escape to the atmosphere through the reflux vent and steam vacuum jets. Phenol and maleic anhydried-modified tall oil rosin esters are also produced. The process operation is very similar to simple rosin ester production except that steam sparging is seldom if ever used, and other polyhydric alcohols may be used in the product formulation.

Rosin-based esters of maleic anhydride, fumaric acid, substituted phenolic, and other modified rosin-based esters, as well as a glycerol phthalate alkyd can be produced under modified conditions. Kettle cook times and pressure conditions vary with type of product. No contact sparge is used at the end of the cook to remove lights and odors. Unwanted materials, such as fatty acids, water of esterification, and sparge steam, are removed from the kettle by means of the vacuum leg. Condensable materials are condensed in a non-contact condenser and separated from the non-condensables in the receiver. Separable materials, such as fatty acids and reaction and reflux oils, are separated from the process wastewaters in the separator. Vacuum jet steam and most noncondensable materials are removed in a scrubber which uses a recirculated oil stream from the separator. The oils are recovered for a secondary market.

BUILDING PAPER AND ROOFING FELT (5)

Stock Preparation

Fibers are prepared for use by various methods which are determined by the fiber source. Wood chips are pulped mechanically in an attrition mill. This is a refiner containing fixed and rotating discs between which the chips pass on a stream of water. In some operations, this is preceded by cooking, or streaming, the chips with water for a short period in a digester, a large metal pressure vessel. This softens the chips and reduces the mechanical energy required. Chemicals are not generally utilized.

The pulp is discharged from the attrition operation as a slurry which goes to a stock chest for storage. It is then blended with other raw materials. Wood flour requires no pretreatment and enters the system in the blending chest.

After they are cut and shredded, rags are placed, along with fresh or process water, in a beater tank at about six percent consistency. Here a rotating cylindrical bladed element, which operates in conjunction with stationary blades, both impacts the fiber and causes its continuous circulation around the beater and back through the attrition zone. Thus, progressive fiberizing occurs. After a period of several hours, when the charge is sufficiently defibered, the pulp is diluted and removed to a dump chest.

Waste paper is similarly treated in beaters or pulpers. In the pulper operation, the paper follows the water circulation in a large open vat and is repeatedly exposed to rotating impeller blades. Over a period of time it is ripped, shredded, and finally defibered. Accessory equipment separates and removes metal and other contaminants.

After the stock is blended, it is subjected to refining and screening ahead of the forming process.

Some building papers are highly sized with resins and alum. Felts may be sized with bituminous materials or contain moldproofing or fungicidal materials.

Papermaking

These products are manufactured principally on single-cylinder paper machines from the raw materials reduced to fiber in the stock preparation area and transported to the machine in a dilute slurry. A rotating wire-covered cylinder retains the fibers which form a sheet on its surface and permits water to drain through. This sheet is then removed from the wire by a cloth felt which carries it through a press section where additional water is removed from the sheet. It is self-supporting as it leaves the press sections and passes through the steam-heated multi-drum drier section from which it is cut to width and rolled. At this stage it is considered a dry or unsaturated felt.

Asphalt Saturating Process

For some products, the paper is carried through one or two stations for asphalt saturation and application of a coat of talc on one side of the sheet. This requires the utilization of cooling water applied by spray nozzles after each saturation which represents the waste load sewered from the area. This process has the capability of making roofing shingles as well as roofing felts; therefore, a section for coating the saturated felt with a granular stone and/or mica is part of the operation.

A process flow diagram of a building paper and roofing felt mill is shown in Figure 27.

SAWMILLS AND PLANING MILLS (6)

The primary function of any sawmill is to reduce a log or cant to a usable end product. The process employed to accomplish this function consists of a combination of basic unit operations including the following:

- mill feed
- log washing
- debarking
- sawing
- resawing
- edging
- trimming
- lumber handling
- lumber finishing

It should be emphasized that several of the above operations may not be practiced at a specific plant. The following process description is a discussion of operations listed above including a discussion of some of the variations within each unit that are most common in the industry.

Mill Feed

The majority of mills utilizing land storage of logs as opposed to water storage are fed by using a variety of loading equipment, most commonly front-end loaders. The loader picks up the log and simply places it on a ramp or deck equipped with moving chains which transport the log into the mill. Some mills, however, utilize ponds or flumes for mill feeding purposes. Ponds may be used for sorting and washing prior to entering the mill. Ponds and other water bodies used for storage are also used for sorting purposes. Log flumes are utilized for mill feeding by relatively few sawmills. In those mills utilizing flumes, ponds or other water bodies for feeding, the logs are floated to the mill entrance where a chain belt or bull chain carries the logs out of the water and into the mill.

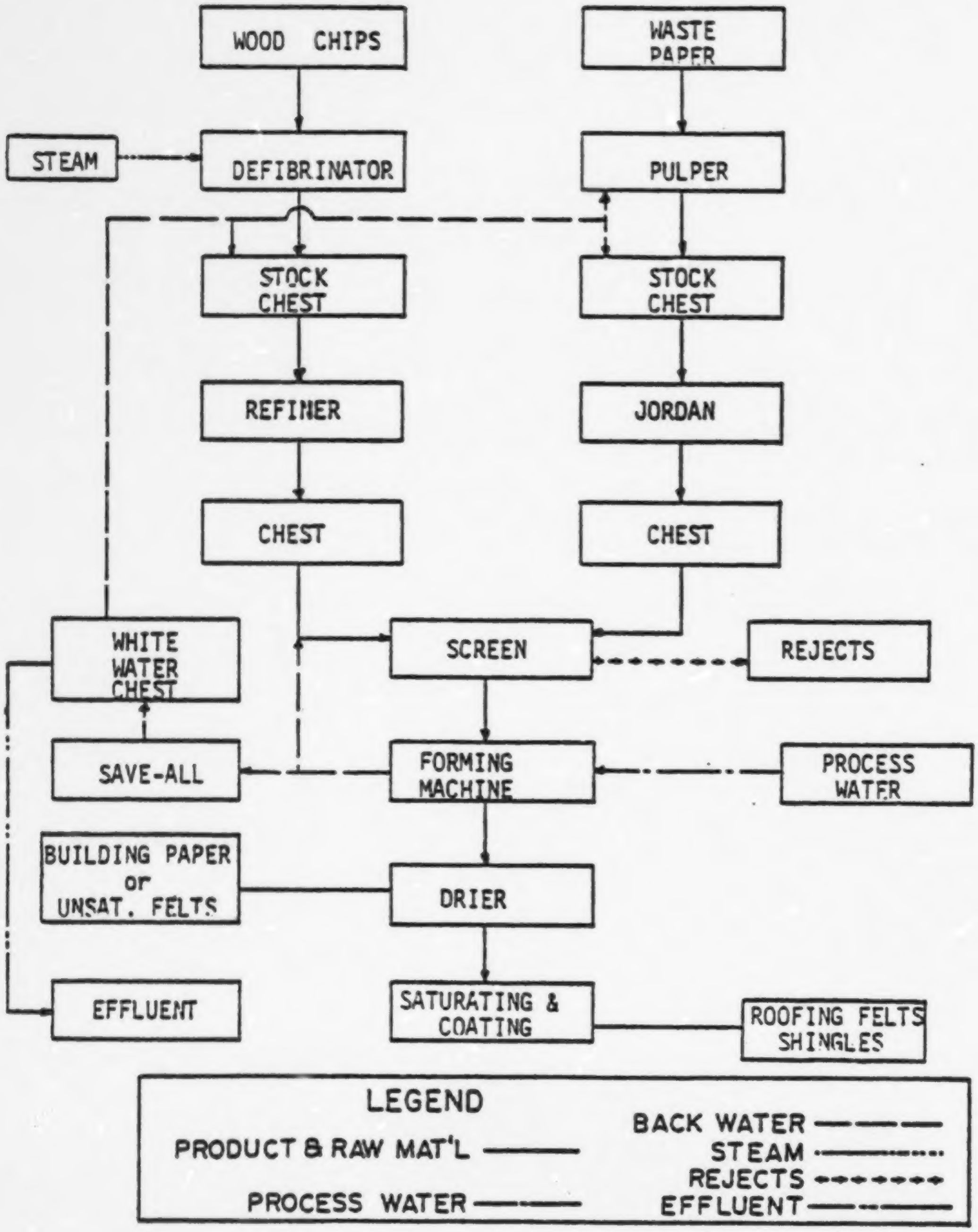
WOOD CHIPS
WASTE PAPER
STEAM
DEFIBRINATOR
PULPER
STOCK CHEST
STOCK CHEST
REFINER
JORDAN
CHEST
CHEST
WHITE WATER CHEST
SCREEN
REJECTS
SAVE-ALL
FORMING MACHINE
PROCESS WATER
BUILDING PAPER or UNSAT. FELTS
DRIER
EFFLUENT
SATURATING & COATING
ROOFING FELTS SHINGLES
LEGEND
PRODUCT & RAW MAT'L
PROCESS WATER
BACK WATER
STEAM
REJECTS
EFFLUENT

FIGURE 27 BUILDING PAPER AND ROOFING FELT PROCESS DIAGRAM(5)

Log Washing

Log washing may be practical prior to barking and/or sawing. While the desirability or necessity of this practice cannot be clearly established, some of the reasons for its use are as follows: (1) where bark is utilized as a fuel, log washing prior to barking reduces the amount of slag buildup on boiler grates and, consequently, reduces frequency of grate washdown. Also, if bark is used for other purposes, a minimal amount of grit is desirable; and (2) for mills not barking prior to sawing, log washing increases saw life.

Log washing is accomplished by spraying water on logs from fixed nozzles as the logs are transported into the mill. In practice, pressure and volume of water utilized vary from mill to mill, but pressures are on the order of 6.8 atmospheres (100 lb per inch^2) while the volume of water varies from less than 5 to 17 lps (80 to 265 gpm).

Headrig Operation

The term headrig is used by the industry to include all the machinery which is utilized to produce the initial breakdown of a log to boards, dimensions or cants. Thus, a headrig includes the feed works, the setworks, the carriage and shotgun, the headsaw, chipper or chipper saw, and all the controls associated with the above.

The basic headrig consists of a single diesel or electric powered circular saw and a log carriage. The carriage is a platform on wheels equipped with hydraulic or electric setworks which hold the log as the carriage moves parallel to the saw. The setworks, which are controlled by the sawyer, position the logs for sawing. The carriage is powered by a shotgun which may be air, hydraulic, or steam powered. The shotgun is a long, circular tube in which a ram is inserted. One end of the ram is attached to the carriage and the other is fitted with a piston head. A compressor or pump pressurizes the working fluid behind the piston and thus powers the carriage in one direction. By rotating a valve spool the sawyer can reverse the direction of the piston and the carriage. Figure 28 gives an equipment layout for a hydraulic shotgun.

Another type of single saw headrig utilizes a band saw. A typical band saw is 25 cm to 30 cm (10 to 12 inch) wide, 11 to 12 m (35 to 40 ft) long, and is mounted on two saw wheels, one above the other, each with a diameter of two to three m (six to ten ft). The band saw is tensioned and driven by the saw wheels and may be one-sided or two-sided. The log is placed on the carriage and sawn as it passes the saw which is moving vertically downward.

Ahead of either the band saw or the circular saw may be a chipper. The chipper is used to square the side of the log prior to sawing and thus eliminates the slab which would otherwise result from sawing.

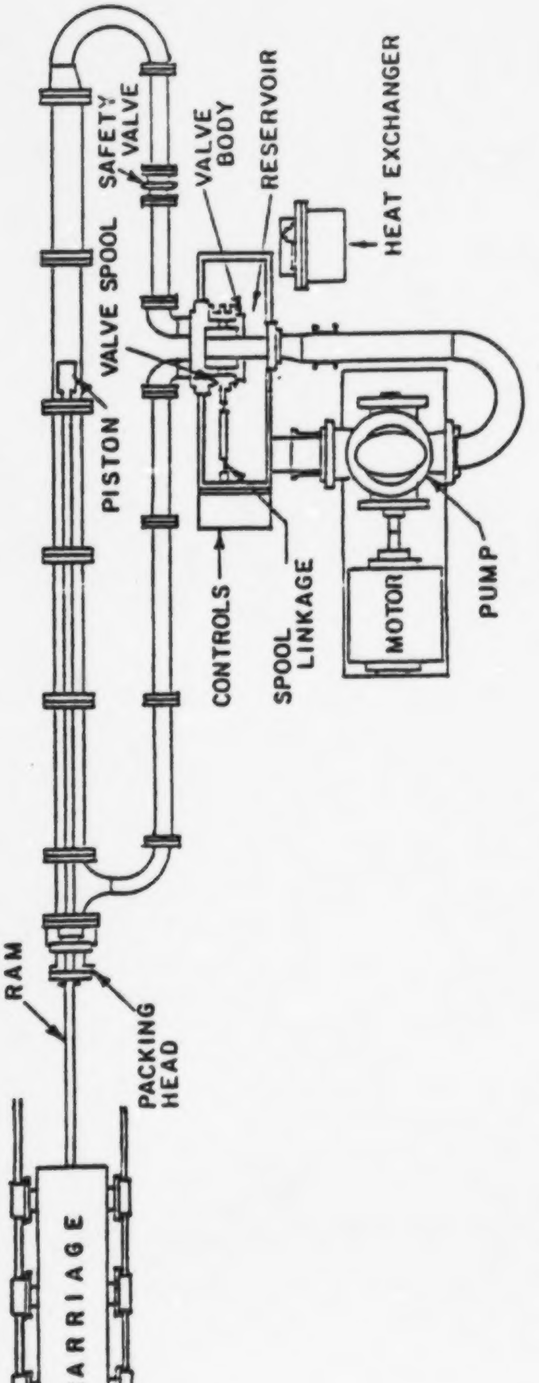
CARRIAGE
RAM
PACKING HEAD
PISTON
VALVE SPOOL
SAFETY VALVE
VALVE BODY
RESERVOIR
HEAT EXCHANGER
CONTROLS
SPOOL LINKAGE
MOTOR
PUMP

FIGURE 28 HYDRAULIC SHOTGUN (6)

The nature of subsequent sawing operations will depend on the degree of breakdown accomplished in the headrig and the desired end product from the mill. In general, the function of these operations is to reduce the width or thickness of the lumber or to square the edges or ends. The basic unit operations following the headrig are gang sawing, resawing, edging, and trimming. The gang saw may be the reciprocating type, or a set of circular saws usually of a movable, double arbor type. The gang saw reduces a cant to lumber of desired thickness. Resaws are usually vertical band saws and are used to saw thick boards into thinner ones. These may be single, double, or quad band resaws. Following resawing, or remanufacturing as it may be termed, the lumber enters the edger. Edgers vary widely in size and capacity but usually consist of one stationary circular saw and one or more circular saws that can be moved laterally on the arbor to permit ripping different widths. Trim saws are circular saws used to square the ends of the lumber and to remove serious defects.

Following edging and trimming, the rough green lumber is sorted and stacked. The lumber may first flow into a green chain and be graded, sorted, and stacked, or it may be graded and sorted by placing it in appropriate sorting troughs. If the lumber is to be marketed green, it may be passed through a preservative bath, usually pentachlorophenol, prior to stacking. The duration of the dip is usually less than one minute.

Dying of lumber is accomplished by either air seasoning or by kiln drying. Air seasoning is accomplished by segregating, coating, and piling. Segregation is done based upon green board weight so that a given pile will dry at the same rate. Prior to its being stacked, the lumber may be treated with chemicals by spraying, brushing, or dipping in order to prevent blue stain and other fungal attack. Various coatings may also be applied to the end of the lumber to retard checking. The most common of these is paraffin or other wax emulsions. The lumber is then stacked in such a manner as to provide adequate air circulation and left to dry for a period of time that may extend to several months.

Kiln drying is accomplished by placing green lumber into a humidity and temperature controlled kiln. The kiln is heated by steam or other means, generally by indirect radiation from coils. Air circulation is maintained by forced draft or by natural circulation. Humidity is controlled by steam sprays. The lumber is stacked mechanically or manually outside the kiln with sticks of wood used to separate the boards. The stacks are then moved into the kiln where they will remain until the desired moisture content is reached. Temperature, humidity, and drying time will vary with kiln type, wood species, initial moisture content, and various other factors. In general, however, kiln drying is accomplished in two to five days at dry-bulb temperatures ranging from 49 to 82°C (120 to 180°F). For some cases, high temperature drying, i.e., above 93°C (200°F) is also employed to reduce drying time.

Dried lumber is quite often planed to desired smoothness. The surfacing tools used are planer knives attached to rotating cutterhead. The quality of finish is a function of the number of knives, the rotations per minute of the cutterhead, the feed rate of lumber through the planer, and other factors. Lumber may be surfaced on one, two, or four sides by the addition of an equal number of cutting heads.

After planing the lumber may proceed through one or more of the following processes:

- preservative dipping
- staining
- end-coating
- moisture proofing

Preservative application is generally accomplished by the methods previously discussed for green lumber handling. Staining, usually with a water base material, is done merely to produce a more pleasing color in the finished lumber. This is generally accomplished by a spray nozzle as the lumber passes through the spray compartment. Excess spray is recirculated. End-coating prevents the ends of the lumber from checking while it is in storage or in service. This is generally done by spraying the end of the lumber with any of various materials such as paint or wax emulsions. Any material which will seal the end of the lumber and is easily applied will suffice. Moisture resistant compounds are sometimes sprayed on the finished lumber to increase durability and resistance to weathering. Compounds specifically formulated for this purpose are available from several manufacturers and are applied in a similar fashion to the stain application discussed above. These materials are generally water soluble.

As previously mentioned, a sawmill is a combination of some or all of the above unit operations. The process diagrams shown in Figures 29 through 31 will serve to illustrate some of these possible combinations and some possible mill layouts.

Figure 29 illustrates a process layout for a small rough green sawmill. Figure 30 illustrates the combination of wet and dry deck storage of logs, with a small to medium size band sawmill and a planing mill. Figure 29 gives a possible layout for a medium-to-large sawmill.

It should be noted that planing mills may exist in combination with sawmills or may be independent mills buying from a number of suppliers. It should also be noted that other unit operations may be present at a sawmill or planing mill. The most common of these additional operations is edge or end jointing of lumber in sawmills and production of millwork in planing mills.

Miscellaneous Operations

There are a number of wood products which are produced by further processing or manufacturing of such primary forest products as lumber, plywood and board products. The large number of such products prohibits a

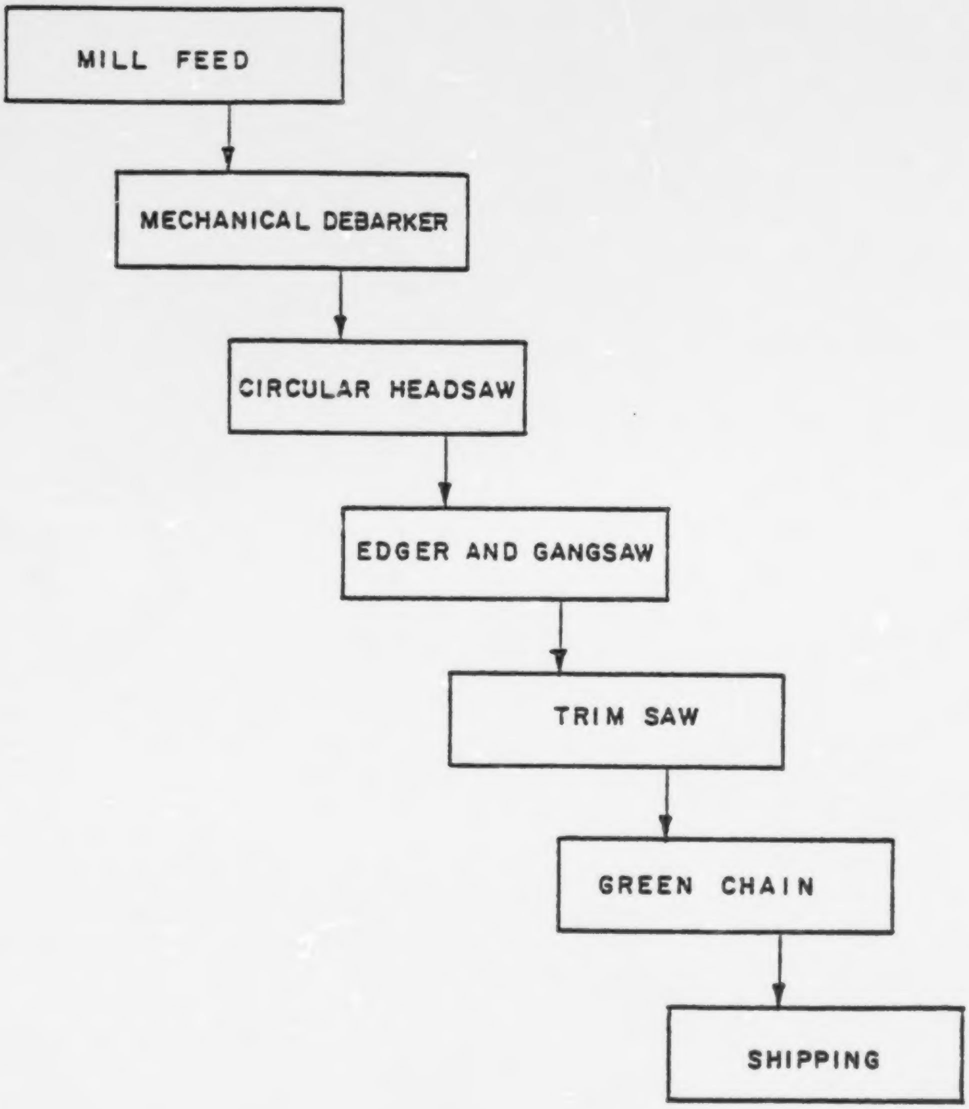
MILL FEED
MECHANICAL DEBARKER
CIRCULAR HEADSAW
EDGER AND GANGSAW
TRIM SAW
GREEN CHAIN
SHIPPING

FIGURE 29 PROCESS DIAGRAM OF ROUGH GREEN SAWMILL (6)

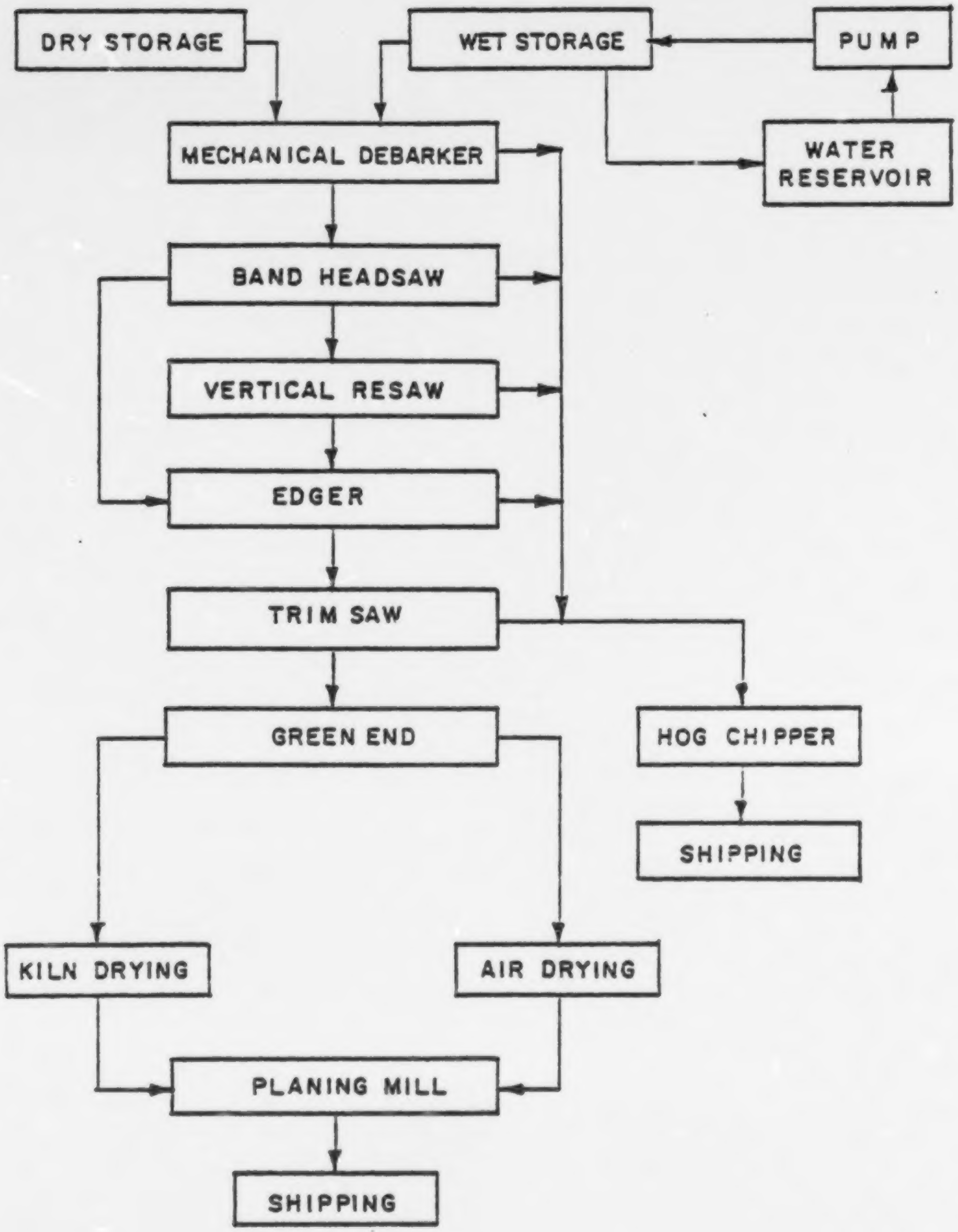
DRY STORAGE
WET STORAGE
PUMP
MECHANICAL DEBARKER
WATER RESERVOIR
BAND HEADSAW
VERTICAL RESAW
EDGER
TRIM SAW
GREEN END
HOG CHIPPER
SHIPPING
KILN DRYING
AIR DRYING
PLANING MILL
SHIPPING

FIGURE 30 PROCESS DIAGRAM OF BAND SAWMILL[6]

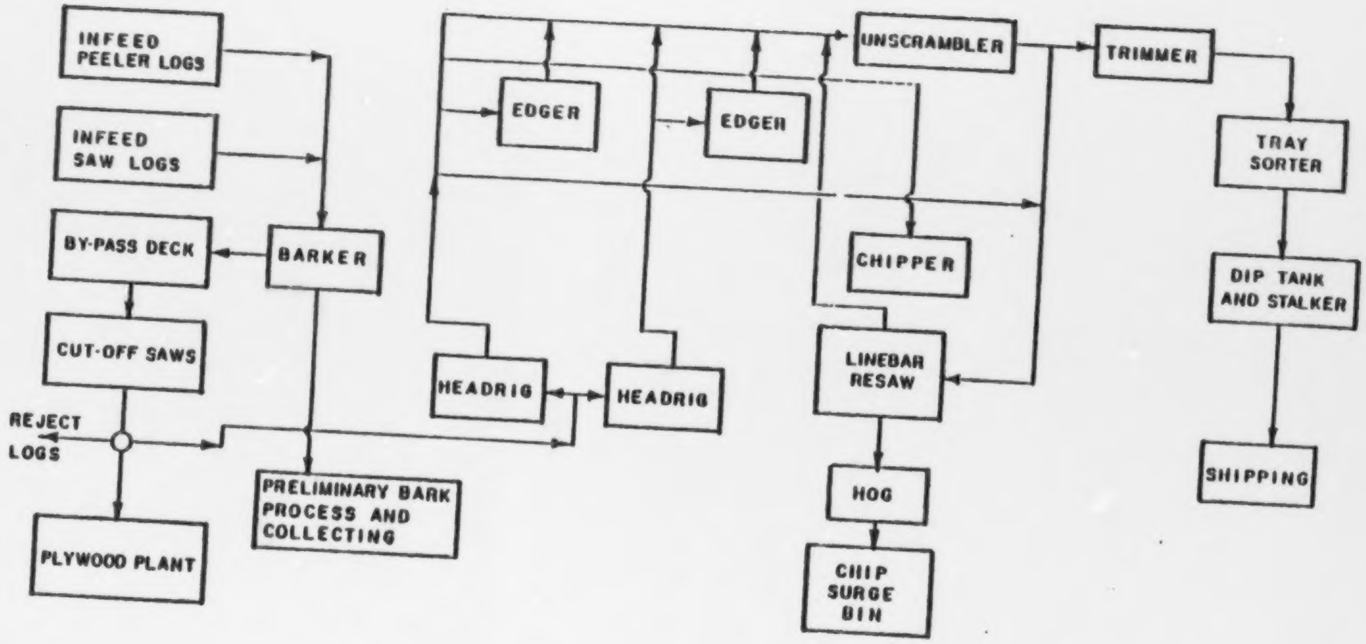
INFEED PEELER LOGS
INFEED SAW LOGS
BY-PASS DECK
BARKER
CUT-OFF SAWS
REJECT LOGS
PLYWOOD PLANT
PRELIMINARY BARK PROCESS AND COLLECTING
HEADRIG
HEADRIG
EDGER
EDGER
UNSCRAMBLER
CHIPPER
LINEBAR RESAW
HOG
CHIP SURGE BIN
TRIMMER
TRAY SORTER
DIP TANK AND STALKER
SHIPPING

FIGURE 31 PROCESS DIAGRAM MULTIPLE HEADRIG SAWMILL (6)

discussion of detailed process descriptions for each individual product and since no hazardous solid wastes are generated in these processes, a thorough discussion of each manufacturing method is unnecessary. Basically the production of miscellaneous wood products may be characterized as one or more of the following unit operations: machining, fabrication, and byproduct utilization. Representative examples of the specific products which are considered under these operations are given below:

Machining

shakes
shingles
excelsior
barrel staves
gun stocks
wooden bowls
door trim
baseboards
moldings
wooden panels
stair railings
toothpicks
wooden frames and sash
window trim
box cleats
spools
flooring
matches

Fabrication

barrels
doors
windows
prefabricated buildings
mobile dwellings
laminated beams
laminated decking
jointed lumber
wooden pipes
trusses
baskets
wirebound boxes
wooden boxes
crates

Byproduct utilization

wood flour
toilet seats
ornamental bark
chair seats
bark mulch
pressed logs

VENEER/PLYWOOD (3)

The various operations for converting roundwood into veneer and finally into plywood are relatively simple and chiefly mechanical. These operations are discussed in the following sections.

Conditioning

Prior to the cutting of veneer, logs may be heated, or conditioned as this serves to improve the cutting properties of wood, particularly hardwood. Historically, both hardboard and softwood mills have practiced log conditioning. There was in recent years a trend away from log conditioning in the softwood industry, but the current trend is again toward this practice.

When conditioning of logs occurs not only prior to veneering, but prior to debarking, it facilitates the barking operation. This has been a common practice in the past. With the increasing use of ring and cutterhead barkers whose operations are not aided by prior heating to the same degree as the wet barking methods, heating commonly occurs between the barking and veneering operations.

There are basically two methods of heating logs: (1) by directing steam onto the logs in a steam vat (steam tunnel), and by (2) heating the logs in a hot water vat full of water which is heated either directly with live steam or indirectly with steam coils.

Heating in steam vats is generally more violent than in hot water vats, the steam vats are therefore more applicable to species of wood that do not rupture under rapid and sudden thermal increases. The times and temperatures of these conditioning processes vary with species, age, size, and character of veneer to be cut. The experience has been that the harder (more dense) the species and the more difficult to cut, the longer the conditioning period and the lower the temperature required. Some of the softer woods, such as poplar, bass wood, cottonwood, and certain conifers, can be cut satisfactorily without such conditioning.

Barking

Barking may be the common starting point throughout the (post harvest, transport and delivery) timber products processing industry. If barking is required, logs are taken to a barker where the bark is removed through one of several wet or dry barking procedures. The logs may be cut to required lengths before or after barking.

Types of barking machines include (1) drum barkers, (2) ring barkers, (3) bag barkers, (4) hydraulic barkers and, (5) cutterhead barkers.

Drum Barkers--

Drum barkers range in size from 2.4 to 4.9 m (8 to 16 ft) in diameter and up to 22.8 m (75 ft) in length. A drum barker consists primarily of one cylindrical shell rotating on its longitudinal axis. Logs are fed into one end and tumbling and rolling action removes the bark. Water sprays may be used to reduce dust, promote the thawing of wood in cold climates, or reduce the bond between the bark and wood.

Ring Barkers--

Ring barkers or rotary barkers consist of a rotating ring on which several radial arms are pivoted. On the end of each arm is a tool which abrades or scrapes off the bark. A ring barker handles only one log at a time, but can handle logs up to 213.4 cm (84 inches) in diameter.

Bag Barkers--

Bag barkers or pocket barkers are simple stationary containers in which the logs are rotated to remove bark by abrasion. Water may also be used in this process for the same purposes described for the drum barkers.

Cutterhead Barkers--

Cutterhead barkers remove bark by the milling action of a cylindrical cutterhead as it rotates parallel to the axis of the logs which are fed through the unit. No water is employed in this operation.

Hydraulic Barker--

The hydraulic barker uses a high pressure water jet to blast bark from a log. Pressures from 55.4 to 110 atm (800 to 1,550 psi) are used with flow in the range of 25.2 to 101 l/sec (400 to 1,600 gpm). Because of the large volumes of low solids content clean water required for this operation, there is an apparent inability to recycle water from this operation, which results in a relatively large volume wastewater discharge. Hydraulic barkers are slowly being phased out because of water requirements and because the oversize logs they process are becoming unavailable.

All of the wet barkers use large amounts of water and it requires a moderately complex operation to separate the bark from the water and dry it for disposal. In spite of the recovery operations, the effluent from wet barkers may have a high solids concentration.

Veneer Cutting

The principal unit process in the manufacturing of veneers is the cutting of the veneer. There are four methods used to cut veneer: (1) rotary cutting, (2) slicing, (3) stay log cutting, and (4) sawn veneering.

Currently more than 90 percent of all veneer is rotary cut. In this method of cutting, a log or bolt of wood is centered between two chunks on a lathe, and a thin sheet of veneer is peeled from the log as it turns. Lathes capable of peeling logs from 3.66 to 4.88 m (12 to 16 ft) in length are not uncommon, but more often veneer is cut in lengths ranging from 0.61 to 2.4 m (2 to 8 ft). The bolts that are to be veneered are usually cut from 10 to 15 cm (4 to 6 inches) longer than the width of veneer to be cut from them.

Most slicers consist of a stationary knife. The section of a log or flitch to be cut is attached to a log bed which moves up and down, and on each downward stroke a slice of veneer is cut by the knife. Slicers are used primarily for cutting decorative face veneers from woods such as walnut, mahogany, cherry, and oak.

Stay log cutting produces veneers which are intermediate between rotary cut and sliced veneers. A flitch is attached to a stay log or metal beam, mounted off center to a rotary lathe. The stay log method produces half-round veneer which is generally used for faces.

A small quantity of veneer is cut by sawn veneering. A circular type saw with a thin, segmented blade, called a segment saw, turns on an arbor. The thin blade reduces the wastage or saw kerf. This method generally is used only for certain species such as oak, red cedar, and Spanish cedar in order to achieve special effects.

Veneers are cut to thicknesses ranging from 0.254 to 9.55 mm (1/10 to 3/8 inch). Most of the rotary cut veneers are either 3.6, 3.2, 2.5, 1.7, or 1.3 mm (1/4, 1/8, 1/10, 1/15, or 1/20 inch) thick. Sliced veneer usually ranges from 1.27 to 0.635 mm (1/20 to 1/40 inch). Sawn veneers vary from 6.35 to 0.795 mm (1/4 to 1/32 inch) in thickness.

After rotary veneers are cut, they may go directly to a clipper or they may be stored temporarily on horizontal storage decks or on reels. Usually the veneer coming from the lathe is cut to rough green size, and defects are removed at the green clipper. From here the veneers are conveyed to the dryers.

Veneer Drying

Freshly cut veneers are ordinarily unsuited for gluing because of their wetness. In the undried (green) state, veneers are also susceptible to attack by molds, blue-stain, and wood-destroying fungi. It is therefore necessary to remove the excess moisture rapidly, and veneers are usually dried to a moisture content of less than 10 percent. This is a level compatible with gluing, and consistent with the moisture content to which plywood products will be exposed while in service.

Several methods for drying veneers are in use. The most common type of dryer is a long chamber equipped with rollers on belts which advance the veneer longitudinally through the chamber. Fans and heating coils are located on the sides of the chamber to control temperature and humidity.

The majority of high-temperature (above 100°C or 212°F) veneer dryers depend upon steam as a heat source. The heat is transferred to the air by heat exchangers. However, direct-fired oil and gas dryers are becoming increasingly common in the industry.

The conventional progressive type and compartment type lumber kilns are also used in drying veneers. Air drying is practiced but is quite rare except in the production of low grade veneer such as that used in crate manufacturing. Air drying is accomplished by simply placing the veneer in stacks open to the atmosphere, but in such a way as to allow good circulation of air.

Veneer Preparation

Between the drying and gluing operations are a series of minor operations that prepare or salvage veneer. These operations may include grading and matching, redrying, dry-clipping, jointing, taping and splicing, and inspecting and repairing. These operations are self-descriptive and completely mechanical or manual except for jointing and splicing which may use some sort of adhesive. The bonding does not have to be as strong as that in the gluing of plywood, and the amount of adhesive used is kept to a minimum. Most of these gluing operations do not require washing.

Gluing Operation

A number of adhesives can be used in the manufacture of plywood. For the purpose of this discussion, distinction is made between (1) protein, (2) phenol-formaldehyde, and (3) urea-formaldehyde glues, since these are the classes of glue most often used in the industry. Protein glue is extracted from plants and animals, while the other two are synthetic, thermosetting glues.

Both protein and urea-formaldehyde glues are chiefly interior glues, while phenol-formaldehyde is an exterior glue. Urea-formaldehyde is used almost exclusively in the hardwood plywood industry when the panels are used for furniture and indoor panelling. Phenol-formaldehyde is a thermosetting resin like urea-formaldehyde, but it is waterproof and is practically the only glue used to make exterior plywood. Phenol-formaldehyde is being used to produce both interior and exterior plywood so that the use of phenol-formaldehyde is increasing rapidly. At present, phenolic glues comprise about 50 percent of all glue consumed.

Historically, protein glues had been the only adhesive used in the plywood industry. However, as a result of synthetic resins becoming less expensive and their versatility becoming more recognized, the use of protein glues is disappearing. At the present time, the main advantage of some protein glues is that they can be cold pressed. However, while cold pressing is a simpler and cheaper operation, it is usually only satisfactory for interior plywood.

Most plywood manufacturers mix their own glue in large dough-type mixers. The glue is then applied to the veneer by means of a spreader, the most common of which consists of two power driven rollers supplied with the adhesive. Protein glues are usually applied with steel rollers, while other glues are usually applied with rubber-covered rollers. More recently the practice of applying glue by means of sprays and curtain coaters has emerged. Since all glues harden with time, the glue system must be cleaned regularly to avoid build-up of dried glue. Some of the more recent spray curtain-coater glue applicators require less washing than the conventional rollers.

Pressing

After gluing, the layers of veneer are subjected to pressure to insure proper alignment and an intimate contact between the wood layers and the glue. The adhesive is allowed to partially cure under pressure. Pressing may be accomplished at room temperature (cold-pressing) or at high temperature (hot-pressing). Cold-pressing is used with some protein and urea-formaldehyde adhesives. Hot-pressing equipment is used to cure some protein, some urea-formaldehyde, and all of the phenol-formaldehyde adhesives.

Most presses are hydraulic and apply pressures from 6.1 to 17 atm (75 to 250 psi). Cold presses are operated at room temperatures, while hot presses are operated at temperatures ranging to 177°C (350°F) with heat being transferred by means of steam, hot water, or hot oil. Plywood pressing time ranges from two minutes to 24 hours depending upon the temperature of the press and the type glue used. Usually, the hotter the press, the shorter the pressing time.

In recent years, radio-frequency heat has been used to cure synthetic resin adhesives. This works on the principle that when an alternating electric current oscillating in the radio frequency range is applied to a dielectric material, the material will be heated. It is questionable whether this method of heating is economically worthwhile, however. It is technically applicable for curing the resin in plywood as well as edge gluing.

Finishing

After the pressing operation, any number of a series of finishing steps, depending upon the operation and the produce desired, may be taken. These operations include (1) redrying, (2) trimming, (3) sanding, (4) sorting, (5) molding, and (6) storing.

WOOD PRESERVING (7)

The wood preserving process consists of two basic steps: 1) preconditioning the wood to reduce its natural moisture content and to increase the permeability, and 2) impregnating the wood with the desired preservatives.

The preconditioning step may be performed by one of several methods including 1) seasoning or drying wood in large, open yards; 2) kiln drying; 3) steaming the wood at elevated pressure in a retort followed by application of a vacuum; 4) heating the stock in a preservative bath under reduced pressure in a retort (Boulton process); or 5) vapor drying, heating of the unseasoned wood in a solvent to prepare it for preservative treatment. All of these preconditioning methods have as their objective the reduction of moisture content of the unseasoned stock to a point where the requisite amount of preservative can be retained in the wood. Preconditioning also results in a more permeable stock allowing penetration of the preservative into the wood as required by American Wood Preservers' Association (AWPA) standards.

Conventional steam conditioning (open steaming) is a process in which unseasoned or partially seasoned stock is subjected to direct steam impingement at an elevated pressure in a retort. The maximum permissible temperature is set by industry standards at 118°C and the duration of the steaming cycle is limited to 20 hours by these standards. Steam condensate that forms in the retort exits through traps and is conducted to oil-water separators for removal of free oils. Removal of emulsified oils requires further treatment.

In closed steaming, a widely used variation of conventional steam conditioning, the steam needed for conditioning is generated in situ by covering the coils in the retort with water from a reservoir and heating the water by passing process steam through the coils. The water is returned to the reservoir after oil separation and reused during the next steaming cycle. There is a slight increase in volume of water in the storage tank after each cycle due to water exuded from the wood. A small blowdown from the storage tank is necessary to account for this excess water and also to control the level of wood sugars in the water.

Modified closed steaming is a variation of the steam conditioning process in which steam condensate is allowed to accumulate in the retort during the steaming operation until it covers the heating coils. At that point, direct steaming is discontinued and the remaining steam required for the cycle is generated within the retort by utilizing the heating coils. Upon completing the steaming cycle, the water in the cylinder is discarded after recovery of oils.

Preconditioning is accomplished in the Boulton process by heating the stock in a preservative bath under reduced pressure in the retort. The preservative serves as a heat transfer medium. After the cylinder temperature has been raised to operating temperature, a vacuum is drawn and water removed in vapor form from the wood passes through a condenser to an oil-water separator where low-boiling fractions of the preservative are removed. The Boulton cycle may have a duration of 48 hours or longer for large poles and piling, a fact that accounts for the lower production per retort day as compared to plants that steam condition.

The vapor-drying process consists essentially of exposing wood in a closed vessel to vapors from any one of many organic chemicals that are immiscible with water and have a narrow boiling range. Selected derivatives of petroleum and coal tar, such as xylol, high-flash naphtha, and Stoddard solvent, are preferred; but numerous chemicals, including blends, can be and have been employed as drying agents in the process. Chemicals with initial boiling points of from 212°F to 400°F (100°C to 204°C) may be used.

Vapors for drying are generated by boiling the chemical in an evaporator. The vapors are conducted to the retort containing the wood, where they condense on the wood, give up their latent heat of vaporization, and cause the water in the wood to vaporize. The water vapor thus produced, along with excess organic vapor, is conducted from the vessel to a condenser and thence to a gravity-type separator. The water layer is discharged from the separator and the organic chemical is returned to the evaporator for reuse.

At the termination of the heating period, the flow of organic vapors to the vessel is stopped and a 30-minute to 2-hour vacuum is imposed to remove the condensed chemical adsorbed by the wood, along with the additional water that is removed from the wood during the vacuum cycle. Since the drying vessel is usually also the retort used for preservative treatment, the wood can be treated immediately using any one of the standard preservative processes.

Following any of the above preconditioning steps, the treatment step may be accomplished by either pressure or nonpressure processes.

Nonpressure (thermal) processes utilize open tanks which contain the preservative chemicals. Stock to be treated is immersed in the treatment chemicals, which may be at ambient temperature, heated, or a combination thereof. Stock treated in nonpressure processes is normally preconditioned by air seasoning or kiln drying.

Treatment methods employing processes consist of three basic types independent of the preconditioning method. Two of the pressure methods, referred to in the industry as empty-cell processes, are based on the principle that part of the preservative forced into the wood is expelled by entrapped air upon the release of pressure at the conclusion of the treating cycle, thus leaving the cell walls coated with preservative. The pressure cycle is followed by a vacuum to remove additional preservative. The retention of preservatives attained is controlled in part by the initial air pressure employed at the beginning of the cycle.

The third method, which is the full-cell process, differs from the other two in that the treating cycle is begun by evacuating the retort and breaking the vacuum with the preservative. The preservative is then forced into the wood under pressure, as in the other processes. Most of the preservative remains in the wood when the pressure is released. Retentions of preservatives achieved in this process are substantially higher than those achieved in the empty cell processes.

Stock treated by any of the three methods may be given a short steam treatment to clean the surface of poles and pilings and to reduce exudation of oil after the products are placed in service.

PARTICLEBOARD (6)

In the majority of cases the raw materials used to produce particleboard are wood residues of any species from other timber product processes. However, roundwood is used in a few instances. At this time, most particleboard in the United States is produced from mill residues such as planer shavings, sawdust, and plywood trim. Furniture waste, particleboard trim, veneer cores, and other chip sources are used occasionally. In cases where a particleboard plant is a part of an integrated complex, a substantial part, or all of the raw materials are supplied by other operations in the complex.

There are three basic steps in producing mat formed particleboard: particle preparation, mat formation, and mat consolidation. Incorporated within these primary operations are particle drying, additive blending, board cooling, and board finishing operations. Figure 32 shows a process flow diagram for particleboard production.

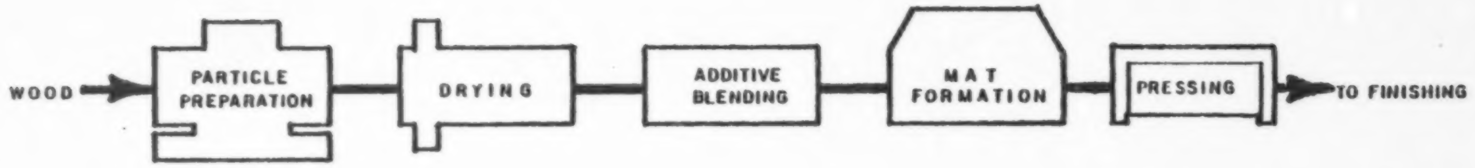
WOOD
PARTICLE PREPARATION
DRYING
ADDITIVE BLENDING
MAT FORMATION
PRESSING
TO FINISHING

FIGURE 32 PARTICLEBOARD PROCESS FLOW DIAGRAM(6)

Classification

Prior or subsequent to particle preparation, it is usually necessary to classify the wood by size by the use of vibrating screens or air classifiers. The classification is done primarily to remove particles of undesired shape and size which, if allowed to remain, would increase the resin requirements, present problems during manufacture, or produce defects in the product. Another reason for classifying particles is to allow the use of the finer particles to form the face of the board and the coarser particles to form the core.

Screen classification is usually accomplished by vibrating screens. The wood is fed onto one end of the screen and the vibrating action of the screen transports the wood along the length of the screen. The rejects which are too large to pass through the screen are recycled back into a system such as a hammermill which reduces the size. The fines which are unacceptable for the process are discarded. Although in some cases air classification provides sharper fractionization, it can also involve greater difficulties in operation and controls. The use of air classification allows for the instantaneous adjustment of the classification process. However, it also entails a larger energy consumption than do screens.

Particle Preparation

The four principle methods of particle formation in use are hammermills, flakers, mechanical, and thermo-mechanical refining. Hammermills and similar type machines use free swinging hammers of steel strips or impellers with stiff arms to reduce material by a beating action. These are relatively simple machines with low cost wear parts. On certain raw materials and with the proper choice of hammermill, operating speed, feed rates, and screen size the hammermill produces acceptable particle geometry at an acceptable cost. Under certain operating conditions, a high percentage of dust may be produced. These machines are used primarily for coarse jobs such as the reduction of large reject chips to a size acceptable for feeding flakers or refiners. These machines are also used to produce some core stock in particular operations. After the initial impact, particles that are still too large are pushed through a screen or grate at the periphery. The screen controls the size of the particles produced.

Flakers are used extensively in the particleboard industry for core stock and to some extent for face stock. Different flakers use either roundwood or residues as the feed; however, the basic concept of the machines, the use of knives to reduce the feed wood to particles, is the same. In the case of wood residue flakers, an impeller throws the residue against a ring of knives. The flakes thus produced are generally 0.05 to 0.15 cm (0.020 to 0.060 inch) in thickness. Thirty to 40 percent of the particles produced are in the screen size range of four to ten with only two to ten percent being larger under normal conditions. Flakers used on roundwood operate on a similar principle in that logs are fed to a rotating set of knives. The resulting flakes are larger than those produced from residue but the thicknesses are comparable.

Mechanical refiners consist of two discs between which the chips or residues are passed. In a single disc attrition mill there is one rotating disc. The feed material passes between the rotating disc and a stationary plate and is discharged at the bottom of the case. Double disc mills have two discs rotating in opposite directions, but the product flow is similar to the single disc mill. The product of disc mills is generally an elongated rod shape. The disc plates generally rotate at 1,200 rpm or 1,600 rpm (a relative speed of 2,400 rpm or 3,600 rpm for a double disc mill). Plate separations are generally less than 0.10 cm (0.040 inch). A variety of disc patterns are available and choice depends on the feed's characteristics and type of product desired. The products from these mills are generally used as face stock, i.e., the fiber is deposited on the surface of the board during formation to provide a smooth surface. When phenolic resins are used, the resin frequently is added during refining.

A thermo-mechanical disc refiner is basically a disc refiner receiving feed material which has been subjected to steam pressure four to 15 atm (60 to 220 psi) for a period of time (15 seconds to 3 minutes) before entering the refiner. The pressure continues through the actual refining (in the disc area), in most cases.

Pre-steaming softens the feed material and thus facilitates refining and reduces horsepower requirements. The longer the pretreatment and higher the pressure, the softer the wood becomes. The heat plasticizes primarily the hemicellulose and lignin components of wood which bind the fibers together. In addition, a longer and stronger fiber is produced.

Drying

Following particle preparation, the particles are dried by heat to achieve a uniform moisture content. The moisture content of the particle is critical and is different for various operations; however, the preferred moisture content of the particles at the dryer exit is usually between 5 and 15 percent. Driers are heated by gas, oil, wood residue unsuitable for particleboard (sander dust, etc.), or a combination of the above, but gas and oil fired driers are most common.

The rotary jet drum drier is essentially a horizontal pneumatic drier in which high velocity heated air is directed in such a manner that a spiral flow of particles is achieved through the drier.

Another type of drier in use is situated vertically and uses a fluidized bed principle. The particles enter the drier and are suspended by hot air entering from the bottom. The particles become lighter as they dry and are emitted from the top of the unit.

A third type of drier in use consists of a tube bundle rotating in a trough. The particles dry in contact with the tube bundles while vanes fitted to the bundles convey the particles. In some cases the particles enter a preheater before entering the drier. The preheater is usually heated by exhaust gases from the main drier.

Because of the nature of the drying operation (heating wood particles), there is always a risk of fire. Although maintenance and operational procedures generally keep fires at a minimum, dryer fires can still be expected to occur several times per year.

The most important operation in terms of the quality of the bond of the board and one of the more critical operations in the particleboard plant is the application of additives. The quantity of resin and the method of application are important factors in both cost and quality of the finished product.

The two most common types of resins used in manufacturing particleboard are urea-formaldehyde and phenol-formaldehyde, with the former accounting for approximately 90 percent of the usage in the U.S. Resin content in the board will range from 6 to 12 percent in the surface layers and 4 to 8 percent in the core. It is sometimes desirable to add 0.25 to 1.0 percent catalyst to urea resin to promote faster curing of the resin. The catalyst, consisting of acids or acid salts such as ammonium chloride, or ammonium sulfate promote faster curing by lowering the pH. The major disadvantage of adding a catalyst is a shortened resin pot life. Ammonium hydroxide may be added to retard the action of the acid until the pressing operation.

In addition to resins, a petroleum base wax sizing is usually added to the particles in the blenders. Sizing increases liquid water resistance considerably and vapor resistance to some extent.

The additives are applied to the particles in blenders of various types. A blender is basically a machine in which wood particles are agitated while a spray of resin and other additives are added in a manner that will allow uniform coverage of the additives on the wood particles. Each wood particle has adequate exposure in the blender to the spray. This insures a coating of the necessary quantity of resin and other additives which is necessary to achieve the desired properties in the final board. The additives may either be mixed together prior to blending or sprayed into the blender separately.

Although most plants currently use continuous blenders there are some batch blenders in use. A batch blender is operated by adding wood to a mix tank and agitating with a proportional amount of additives. While this system is considered by the industry to be reliable it is not economically feasible for large plants and is rarely used.

Continuous blenders consist of a longitudinal trough with a center shaft carrying mixing arms and spray nozzles for the dispersion of additives. There are two common types of continuous blenders. In one type the mixing arms rotate and cause a dense wood-air suspension. Spray nozzles located along the top eject atomized resin and other additives onto the particles in a uniform manner. The atomization is accomplished by compressed air, pressure spraying, or, in some cases, centrifugal means.

Formation of a uniform mat of particles is the single most important objective in a particleboard manufacturing process. A lack of uniformity will result in physical property variations, curing problems in the pressing cycle, and will tend to make the particleboard more subject to warp. Poor mat formation will also result in poor surface and edge characteristics which in turn affect the salability of the board.

Forming machines meter the particles from a surge area and spread them uniformly across the width of the machine onto a caul or moving screen. In addition, there is usually a particle orientation or leveling device to further provide for uniform continuity of material flow into the formation devices. It is important to maintain a uniform level in the surge bin. Without bulk density control there can be no uniform mat formed as the wood is generally metered volumetrically. The wood is metered onto the caul or moving screen by the means of rakes, picker rolls, or other such devices, although some machines use air as a metering technique. After the particles are distributed onto the caul or moving screen, there are usually leveling screws or picker rolls or shaveoffs to level the mat. To produce a layered board, the particles, which have been previously divided into fine and coarse materials, are laid by different machines to give fine surfaces and a coarse core to the board.

A variation of the layer board formation is the graded density board. This is formed by air classification and a gradual reduction of particle size occurs from the core to the surface. Graded density is accomplished by feeding particles at a volumetrically controlled rate through a central air distribution mechanism. The horizontal air flow acts as an air separator and the heaviest particles drop almost vertically, while the finer particles are thrown to the far edges.

Pressing

After formation the mats are conveyed to the pressing area. A prepress is often used when a caul-less system is being used or a thick board is being produced. The prepress, which may be of the single opening hydraulic type or the continuous roller type, is used to impart some integrity to the board before it enters the hot press. Also, before entering the hot press, the mats are usually trimmed by trim saws with the trim being recovered as furnish and fed back to the forming system.

The hot press is used to consolidate the mats under pressure and cure the resin with the heat from the steam heated platens. Some newer plants use resonance frequency devices to help cure the resin by heating the board internally with the use of high frequency radio waves. Resonance frequency pressing reduces press time and allows for the production of boards of greater thickness.

Pressing is accomplished by either multi-opening hydraulic presses, single opening hydraulic presses, or, occasionally, a continuous press. Multi-opening presses consist of a number of shelves with each shelf containing a heated platen. The mats are stacked into a loader which in turns allows mats to be placed on all the shelves at once. Each press is usually constructed so that platens close simultaneously in order to prevent board defects. Single opening presses do not require loading racks. They operate in a similar manner as the multi-opening presses. The presses operate at pressures as great as 69 atm (1,000 psi) and at temperatures of 132° C to 204° C (270°F to 400°F) depending upon the type of resin and process employed. Continuous presses consist of heated rolls and produce a continuous ribbon of board. After the ribbon leaves the press it is cut to the lengths required and sanded.

Extruded Particleboard

The raw materials utilized for extruded particleboard are usually dry wood with a large proportion of furniture scrap. Particle preparation is primarily accomplished by hammermills. After particle preparation and classification, the wood particles are coated with resin and wax by the previously described batch method. The coated particles are forced through a heated dye by hydraulic rams and the board emerges in a continuous strip which is cut to size. Since boards produced by the extrusion process are considerably stronger in one direction they are usually cross-banded with wood veneers to provide strength and stability.

Finishing Operations

Finishing is generally the final step, with the exception of packaging, in any timber products manufacturing process. It may consist of surface smoothing such as sanding or planing, covering with liquid coatings, or covering with various sheet materials, or combinations of these operations.

Factory finishing of wood-based panel products involves the application of a wide variety of finishing materials of various formulations and the employment of various methods of application. In general, however, finishing materials can be classified as either liquid materials or sheet material overlays. Liquid finishes are supplied to almost all types of wood-based panels including softwood plywood, hardwood plywood, hardboard and particleboard. For any particular finishing operation, the finishing material used and the method of application are primarily depending upon the type of panel being finished as well as the desired final properties of the finished product. Liquid finishing materials are most commonly applied by one of the following methods: spray coating, curtain coating, direct roll coating, reverse roll coating, or knife coating. Each of these methods usually involved the employment of a coating machine through which the panel substrates pass in a horizontal position, on a continuous basis by way of a conveyor system.

Liquid finishing materials vary widely and cannot be defined as completely as the methods employed in their application. Finishing operations on all types of wood-based panel substrates usually involve the application of one or more of the following materials: patching materials, sealers, stains and dyes, prime coatings and fillers, base or ground coatings, grain printing inks, and top coatings. Patching materials are usually applied to hardwood plywood panels as the first step in the manufacturing of prefinished wall panels. The patching material, a thick putty-like substance, is manually applied using a flat blade putty knife to fill knot holes and other large surface defects in the hardwood face veneer of the panels.

Overlaying operations in the factory finishing of wood-based panels involves various types of sheet materials being bonded to the base panel by glue or cement materials or various types. The primary purposes of overlaying are to mask defects, protect against weathering, provide a base for paints and other finishes, increase the strength, hardness or abrasive resistance of the surface, provide decorative effects, or a combination of any of these attributes. The most important types of overlaying materials are resin-impregnated papers, special plastic film and aluminum foils. Resin-impregnated paper overlays are used on all types of wood-based panels. The resin-impregnated papers or widely varying resin content are usually bonded to the wood-based panel under high temperatures and pressures. Temperature ranges of 93° to 149°C (200° to 300°F) and pressure of 8 to 28 atm (118 to 412 psi) are employed depending on the resin type and content and on the type of base panel being overlaid. Except in the production of abrasion resistant surfaces, most overlaying operations involve low pressure systems. For surfaces where high resistance to abrasion is required, high pressure laminating of a clear melamine protective sheet is often added to the overlayed panel.

Special plastic films of various types may be used to overlay almost all types of wood-based panels. Vinyl resin films are being used to a large extent. Polyvinyl chloride films are used in producing textured and printed decorative panels. Clear vinyl films are also important in finishing hardwood plywood wall panels. Bonding of the vinyl film is usually accomplished through the application of either polyvinyl acetate water-emulsion adhesives or solvent-type elastomeric adhesives. The polyvinyl acetate is a thermoplastic resin formed by polymerization of vinyl acetate. The adhesive is either applied to the wood-based panel or to the vinyl film and is often dried to remove the solvent, then heat activated before joining the two materials. The overlayed panel is usually pressed between two rubber rollers to improve the bond.

Aluminum foil overlayed panels are being produced on a relatively small scale basis. Bonding of the foil is often accomplished by using modified phenolic resin film glue and employing a press operation. Adhesives used in the overlaying operations discussed above can be applied in a number of ways, but the most common method is by roll coating the adhesive onto the panel substrate prior to the application of the sheet material overlay.

Other types of overlaying operations practiced on a relatively small scale basis involve the overlaying of hardboard and veneers onto particleboard panel substrates. Adhesives used in these operations are most commonly phenolic or urea resin glues used in conjunction with a hot pressing operation. However, vinyl glues and various contact cements can also be used in a cold pressing operation.

WOOD FURNITURE MANUFACTURING (8)

The following discussion of the furniture manufacturing process is intended to provide a general knowledge of the operations involved in the industry. It must be realized that considerable variation occurs and that all plants are different to varying degrees. Figures 33 and 34 illustrate the overall process.

Raw Material Handling and Storage

The principal raw materials used in furniture manufacturing are lumber, veneer, plywood, hardboard, and particleboard. Occasionally, if a plant is sufficiently large, timber may be purchased or cut from the plant's own forest lands and then processed to rough dimension at its own rough mills. Particleboard or hardboard mills are usually associated with such an operation to utilize the waste wood from the rough mill and furniture plant. Otherwise, and particularly in small operations, composition panels and plywood panels are purchased.

Lumber is usually stored in an area protected from the weather until it is ready for kiln drying. After kiln drying the lumber enters a dry storage area where a five to six percent moisture content is maintained.

Machining

The first step in the processing of raw materials into furniture occurs in the machine room where the stock is cut to length, ripped to width, and planed to thickness. This may be a completely automated operation in a large plant or manual operation in a smaller plant. From this point the stock is passed on to further cutting where it is face finished, by such means as routing, boring, etc., and edge or end cut for joining. Prior to assembly, the stock is sanded on all faces that will be exposed on the finished product.

When composition board and plywood are used as finished surfaces they are either veneered or laminated prior to reaching the furniture assembly line. These panels may be cut and edge finished to the exact size of the finished product or cut to rough dimension and edge finished at a process farther down the assembly line. The panel surface may be left unfinished at this point and later finished with the furniture unit, or it may be prefinished by a printing process or lamination.

Wood Bending

Wood has good bending stress qualities about the longitudinal axis of grain but has rather poor stress qualities about the lateral axis. When a curved or serpentine piece of wood is required for strength, it may be

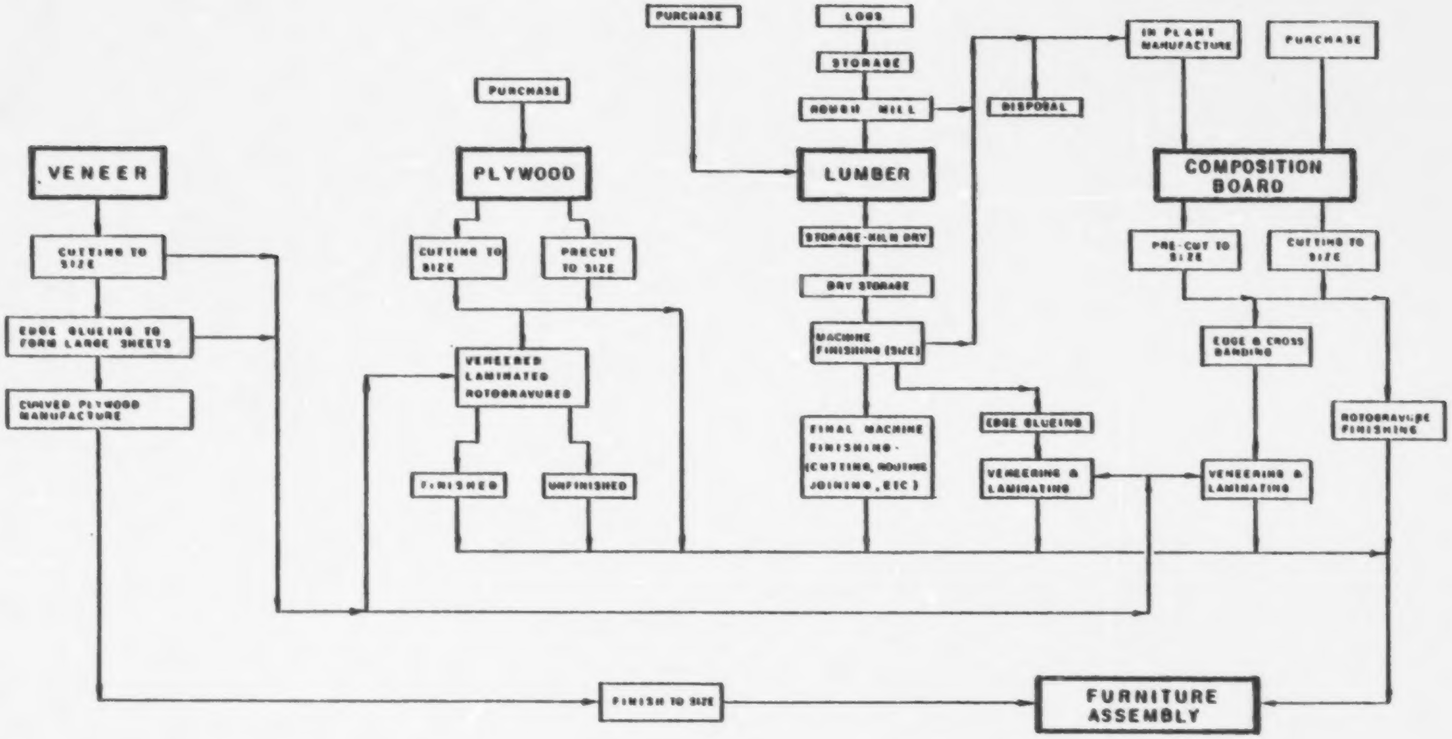
VENEER
CUTTING TO SIZE
EDGE GLUEING TO FORM LARGE SHEETS
CURVED PLYWOOD MANUFACTURE
PURCHASE
PLYWOOD
CUTTING TO SIZE
PRECUT TO SIZE
VENEERED LAMINATED ROTOGRAVURED
FINISHED
UNFINISHED
PURCHASE
LOGS
STORAGE
ROUGH MILL
LUMBER
STORAGE-KILN DRY
DRY STORAGE
MACHINE FINISHING (SIZE)
FINAL MACHINE FINISHING- (CUTTING, ROUTING JOINING, ETC)
DISPOSAL
EDGE GLUEING
VENEERING & LAMINATING
IN PLANT MANUFACTURE
PURCHASE
COMPOSITION BOARD
PRE-CUT TO SIZE
CUTTING TO SIZE
EDGE & CROSS BANDING
VENEERING & LAMINATING
ROTOGRAVURE FINISHING
FINISH TO SIZE
FURNITURE ASSEMBLY

FIGURE 33 FURNITURE MANUFACTURING PROCESS DIAGRAM - PREFINISHING (8)

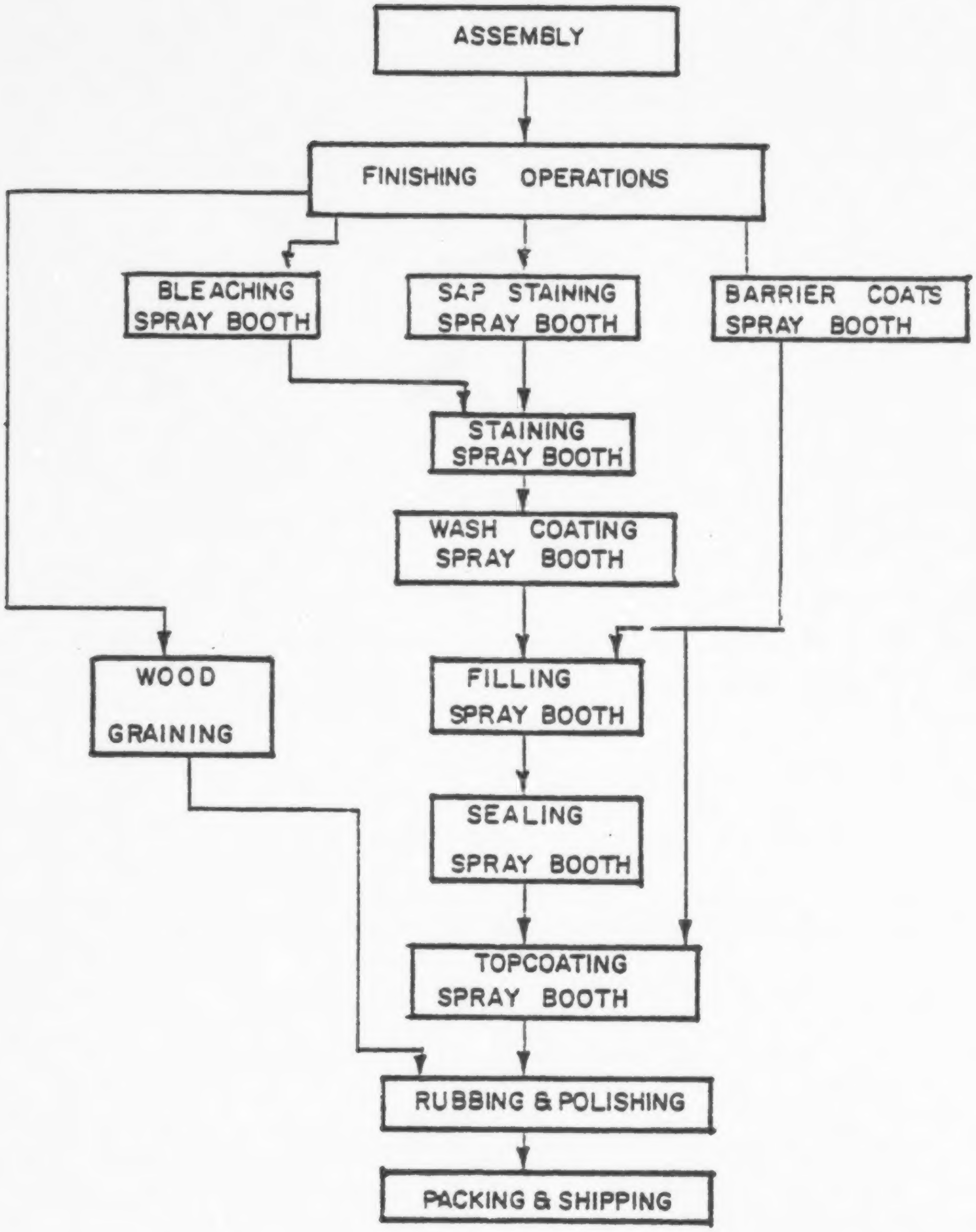
ASSEMBLY
FINISHING OPERATIONS
BLEACHING SPRAY BOOTH
SAP STAINING SPRAY BOOTH
BARRIER COATS SPRAY BOOTH
STAINING SPRAY BOOTH
WASH COATING SPRAY BOOTH
WOOD GRAINING
FILLING SPRAY BOOTH
SEALING SPRAY BOOTH
TOPCOATING SPRAY BOOTH
RUBBING & POLISHING
PACKING & SHIPPING

FIGURE 34 FURNITURE MANUFACTURING PROCESS DIAGRAM - FINISHING(8)

composed of small pieces of wood glued together to form a longitudinal grain or may be a single piece of wood bent by the process of steam application.

The first step in the steam bending process is to cut the wood to a predetermined size and length. It is then placed in a steam chamber or retort under atmospheric pressure for a period of time, usually approximately 30 minutes, depending upon the wood species and size. The wood is then placed in a flexible metal band and bent to shape in a hydraulic bender. The band is secured by metal straps and wood spacers are inserted to hold the wood in the bent shape after pressure is released from the bender. The strapped wood is then oven dried and cooled at a controlled rate. Thin pieces of wood are bent in the same manner except they can be bent by hand over a mold and held in place by other means until dried and cooled.

Assembly

After all component parts have been fabricated, they are transported to the assembly area. In this stage of the process the parts are fastened together by the use of metal fasteners (nails, screws, staples, etc.) and/or glued joints. Subassemblies are fabricated and in turn are passed down the assembly line for final fabrication.

Glue may be used at any of several points in the assembly process depending on the type of product being made. Generally, a higher quality product will have both glued and metal fastened joints.

The application of glue involves the use of either hand held bottles or automatic machines. The two general types of glue used are solvent base and water base, such as urea glue that requires water for mixing.

Finishing Operations

After complete assembly, the furniture components are transported to the finishing room where the steps shown in Figure 34 are carried out. The primary purposes of finishing, for both inexpensive and expensive furniture, are beautification, protection, and preservation to the wood. The finish prevents excessive absorption of atmospheric moisture which would cause swelling and warping of the wood. It also provides resistance to surface soiling and staining. It is possible to provide wood with sufficient protection for average conditions of interior service with a simple finish coat of lacquer, varnish, or enamel paint. However, the demand for refinement requires a considerable number of operations and finishing materials. A summary of these operations and materials is presented in the remainder of this section.

As illustrated in Figure 34, finishing operations typically consist of the following:

1. Bleaching is the use of a strong oxidizing agent such as hydrogen peroxide to remove or subdue the natural wood colorant.

2. Staining, done after bleaching if bleaching is required, involves the application of transparent or semitransparent liquids made from dyes, finely divided pigments, or chemicals. The purpose of staining is to provide an undertone to the finished wood.

3. Filling is the application of a solution consisting of translucent, inert pigments, a vehicle binder, and thinners. Fillers are normally applied to woods with large pores in order to fill the pores and make the pattern of the wood stand out more clearly.

4. Sealing prevents the transfer of materials from one finish coat to another. Sealers may be applied on bare wood as a barrier coat, between the stain and filler as a wash coat, or after the filling operation as a prime coat.

5. Topcoating is the application of a lacquer or, less commonly, a varnish to the wood as a final protective coat.

6. Wood graining is the process of printing a wood grain on the surface of composition board, plywood, or solid wood.

The various finishing materials may be applied by brush or roller, but most often they are sprayed onto the wood surfaces. Spraying operations, as shown in Figure 34, require the use of spray booths to collect and contain the overspray and thus provide fire and health protection. The air drawn into the booth from the object being sprayed is filtered by one of several methods before discharge to an outside source.

1. U.S. Environmental Protection Agency. A Guide to the Selection of Cost-Effective Wastewater Treatment Systems. EPA-430/9-75-002, 1975.

2. U.S. Environmental Protection Agency. Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Unbleached Kraft and Semichemical Pulp Segment of the Pulp, Paper, and Paperboards Mills Point Source Category. May 1974.

3. U.S. Environmental Protection Agency. Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Bleached Kraft, Groundwood, Sulfite, Soda, Deink, and Nonintegrated Paper Mills Segment of the Pulp, Paper, and Paperboard Mills Point Source Category. August 1975.

4. Choi, P. S. K., et al., Battelle Columbus Laboratories. Multi-Media Pollution Assessment in Pulp, Paper, and Other Wood Products Industry. Unpublished work prepared for the Food and Wood Products Branch, Corvallis Field Station, U.S. Environmental Protection Agency, September 1976.

5. U.S. Environmental Protection Agency. Development Document for Interim Final Effluent Limitations, Guidelines and Proposed New Source Performance Standards for the Gum and Wood Chemicals Manufacturing Point Source Category. EPA 440/1-76/060b, April 1976.

6. U.S. Environmental Protection Agency. Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Builder's Paper and Roofing Felt Segment of the Builder's Paper and Board Mills Point Source Category. May 1974.

7. U.S. Environmental Protection Agency. Development Document for Proposed Effluent Guidelines and New Source Performance Standards for the Wet Storage, Sawmills, Particleboard, and Insulation Board Segment of the Timber Products Processing Point Source Category. August 1974.

8. Environmental Science and Engineering, Inc. Revised Technical Review of the Best Available Technology Best Demonstrated Technology and Pretreatment Technology for the Timber Products Processing Point Source Subcategory. 1978.

9. U.S. Environmental Protection Agency. Development Document for Proposed Effluent Limitations Guidelines and New Source Performance Standards for the Wood Furniture and Fixture Manufacturing Segment of the Timber Products Processing Point Source Category. November 1974.

APPENDIX B. EFFLUENT TREATMENT COST CURVES

Capital and operation/maintenance (O&M) cost estimates for various wastewater treatment technologies have been published in a technical report by the U.S. Environmental Protection Agency.(1) Cost relations from this reference are presented in Figures 33 through 42. Actual treatment costs would be affected by several factors including: 1) raw effluent characteristics, 2) required removals, 3) local conditions, and 4) inflation. Thus, the information presented in Figures 33 through 42 may be used to determine relative costs of various technologies; however, any specific cost values must be viewed with much caution.

Currently, the estimated costs and associated economic impacts associated with various degrees of treatment of wood products industry effluents are being evaluated for BATEA guidelines development. The completion of this work will provide a clearer picture of the costs for additional wastewater treatment.

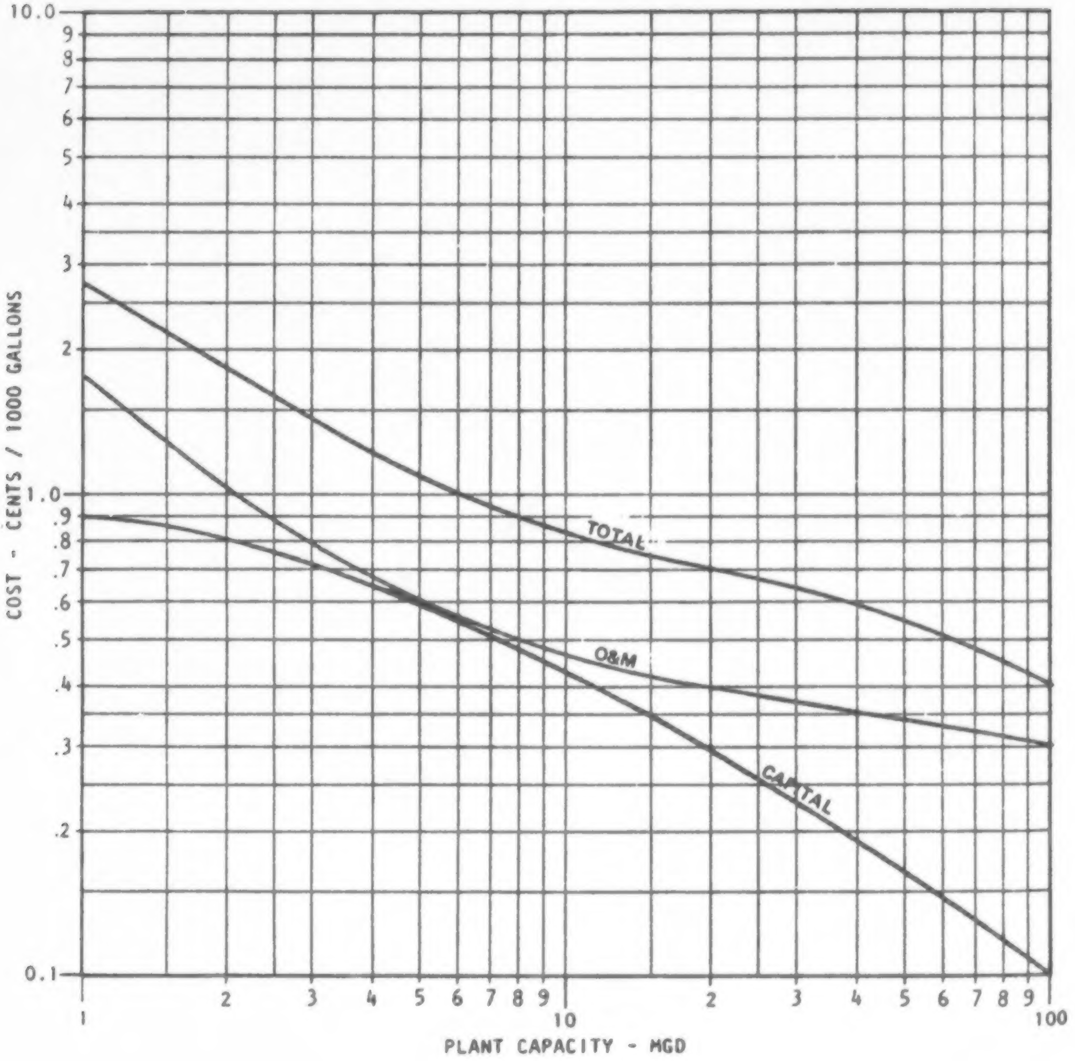

FIGURE 35

AA. PRELIMINARY TREATMENT

Influent: Raw Wastewater

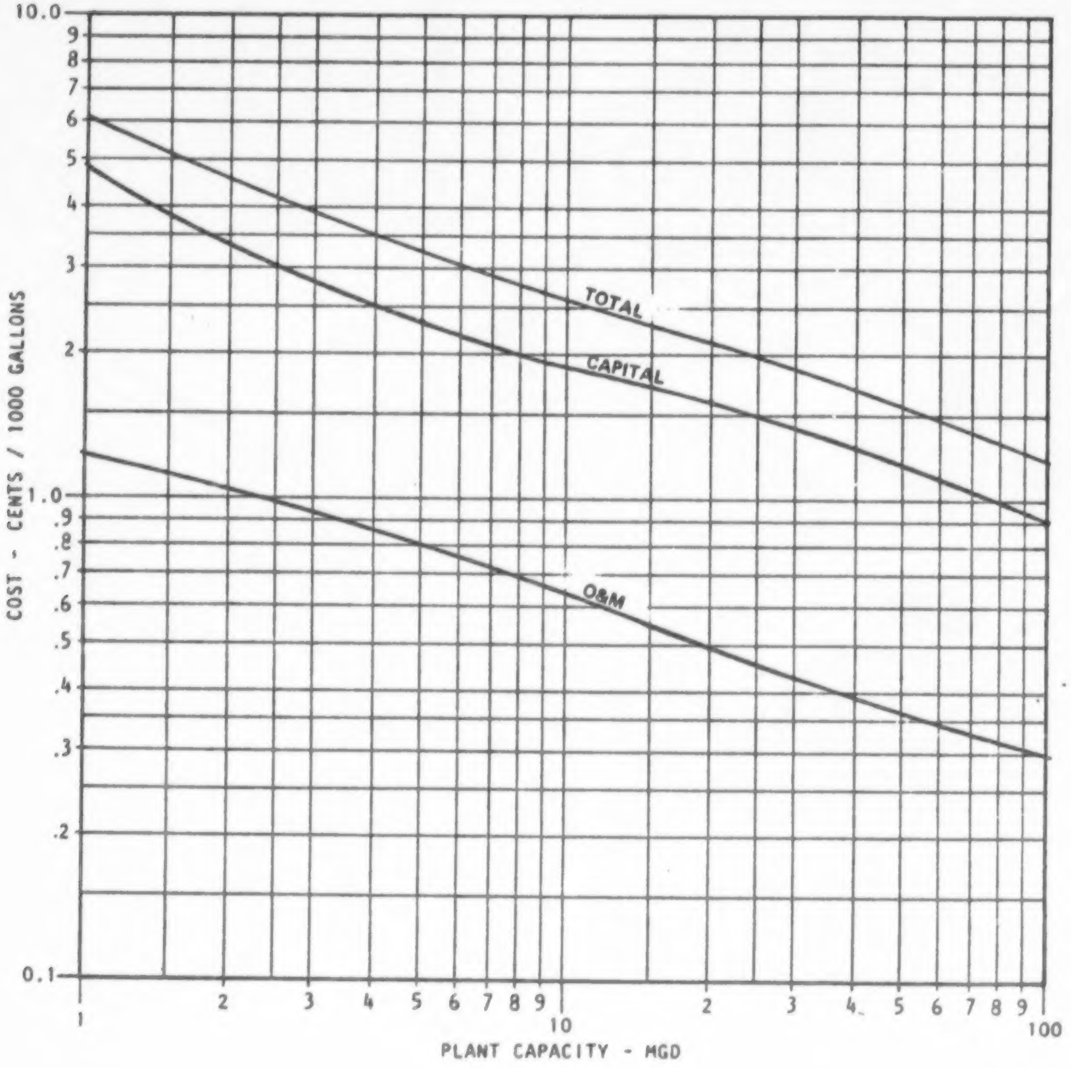

FIGURE 36

AB. RAW WASTEWATER PUMPING

Influent: Effluent from Preliminary Treatment AA

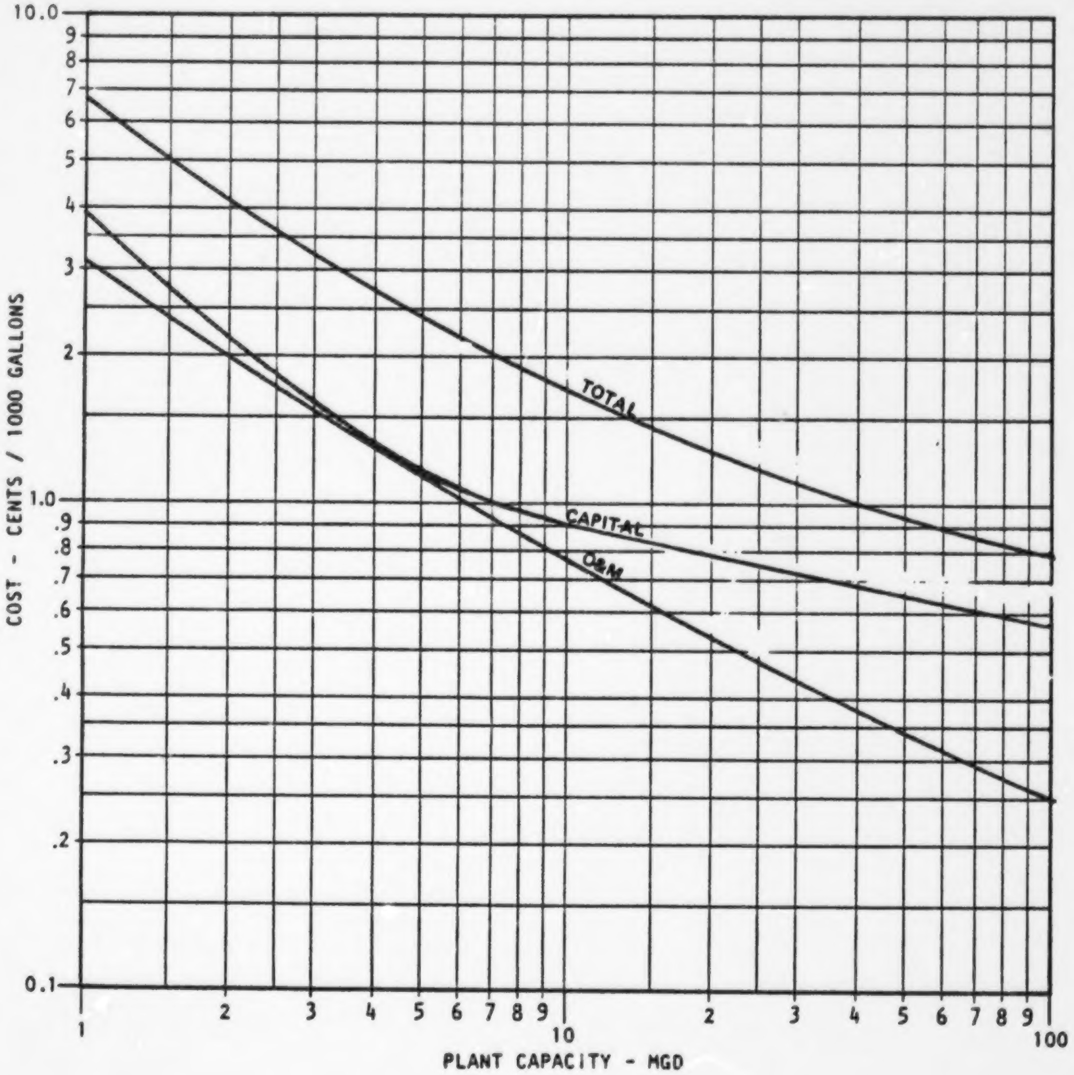

FIGURE 37

A-1. PRIMARY SEDIMENTATION – CONVENTIONAL

Influent: Effluent from Preliminary Treatment AA or Raw Wastewater Pumping AB

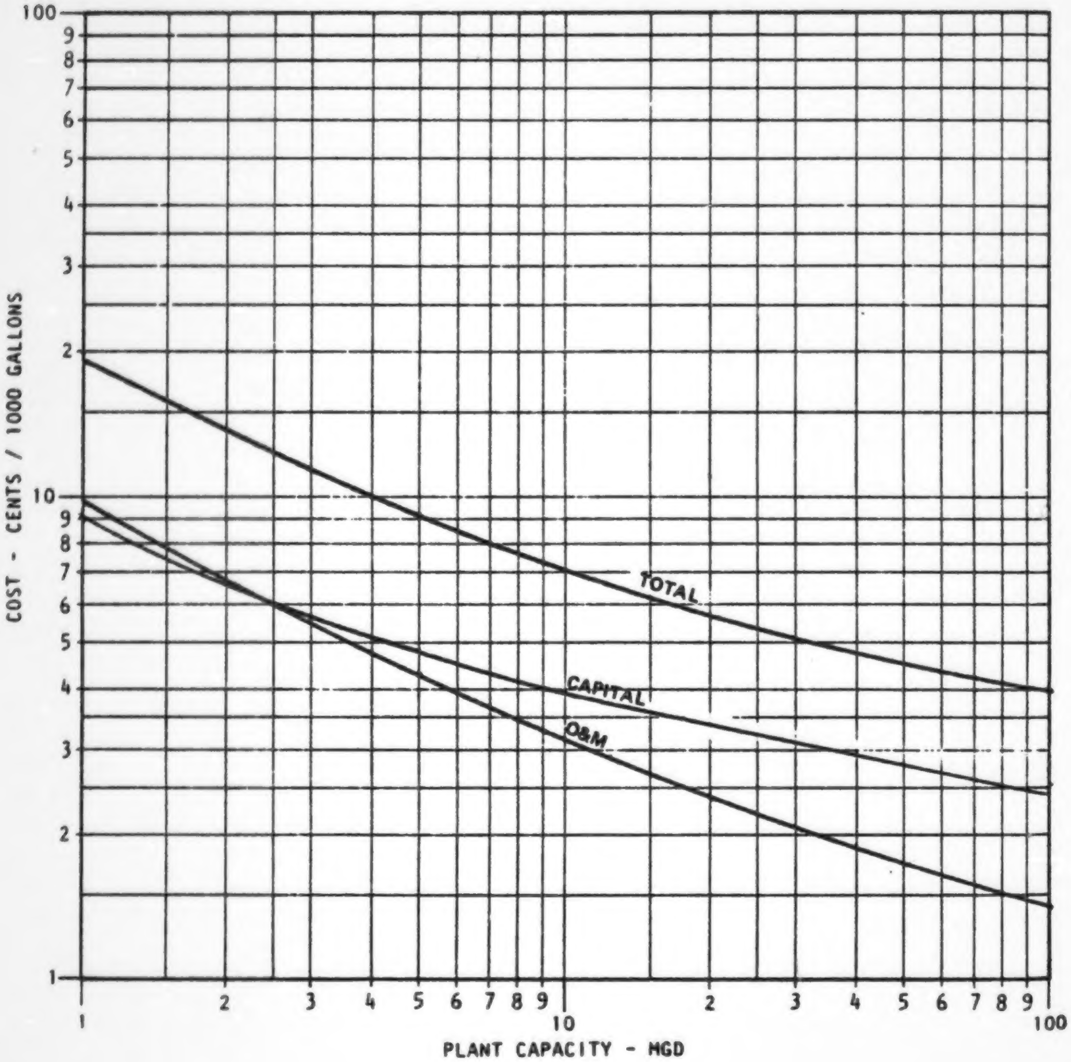

FIGURE 38

C-1. ACTIVATED SLUDGE – CONVENTIONAL

Influent: Effluent from Primary Sedimentation – Conventional A-1

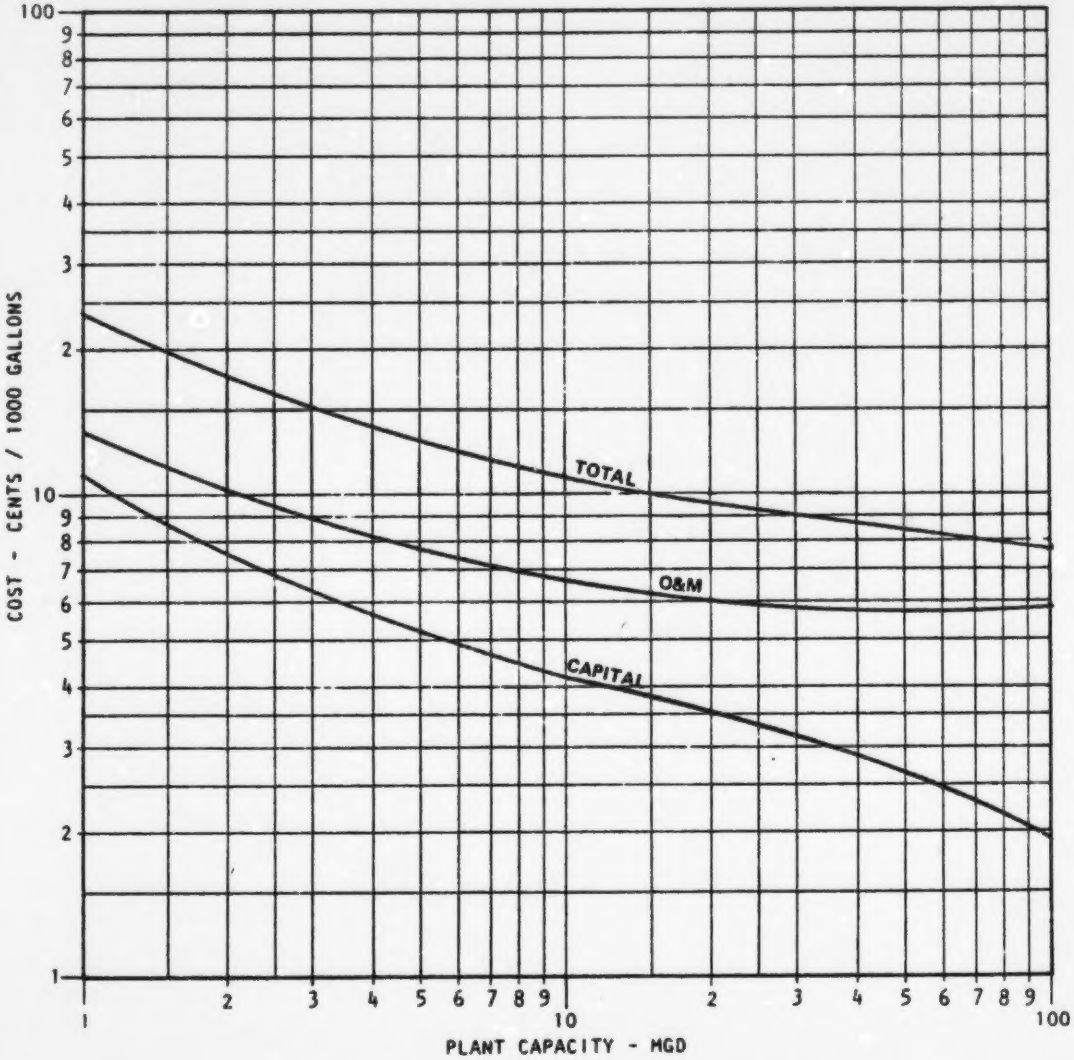

FIGURE 39

C-4. ACTIVATED SLUDGE + ALUM ADDITION
Influent: Effluent from Primary Sedimentation – Conventional A-1

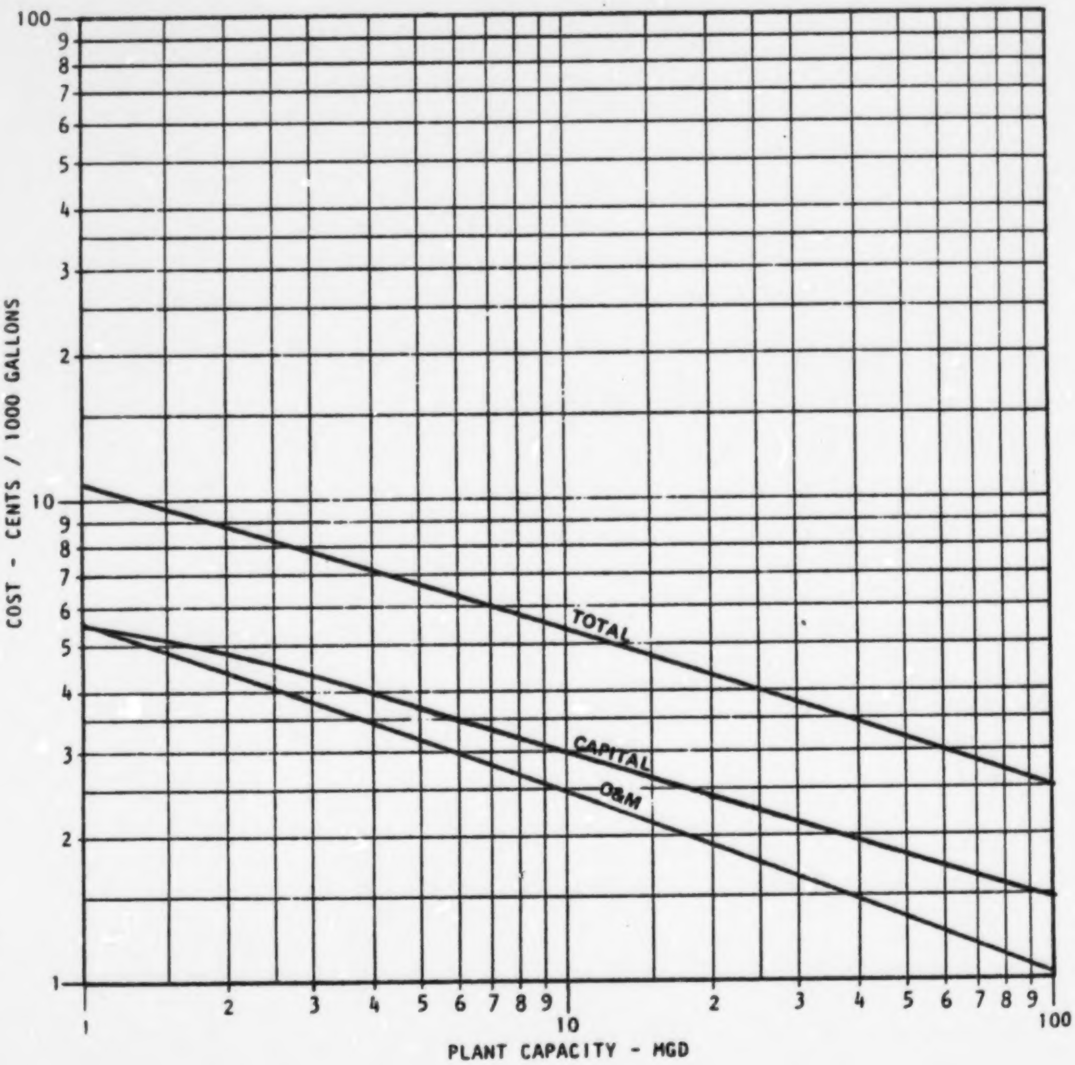

FIGURE 40

D. FILTRATION

Influent: Effluent from Primary Sedimentation – Two Stage Lime Addition
A-2
Activated Sludge – Alum or $FeCl_3$ Addition
C-4 or C-5
Two Stage Tertiary Lime Treatment
F-1 or F-2
Trickling Filter B-2, B-3
Activated Sludge C-2, C-3
Biological Nitrification G-1, G-2, G-3, G-4
Biological Denitrification H
Breakpoint Chlorination J
Ammonia Stripping K

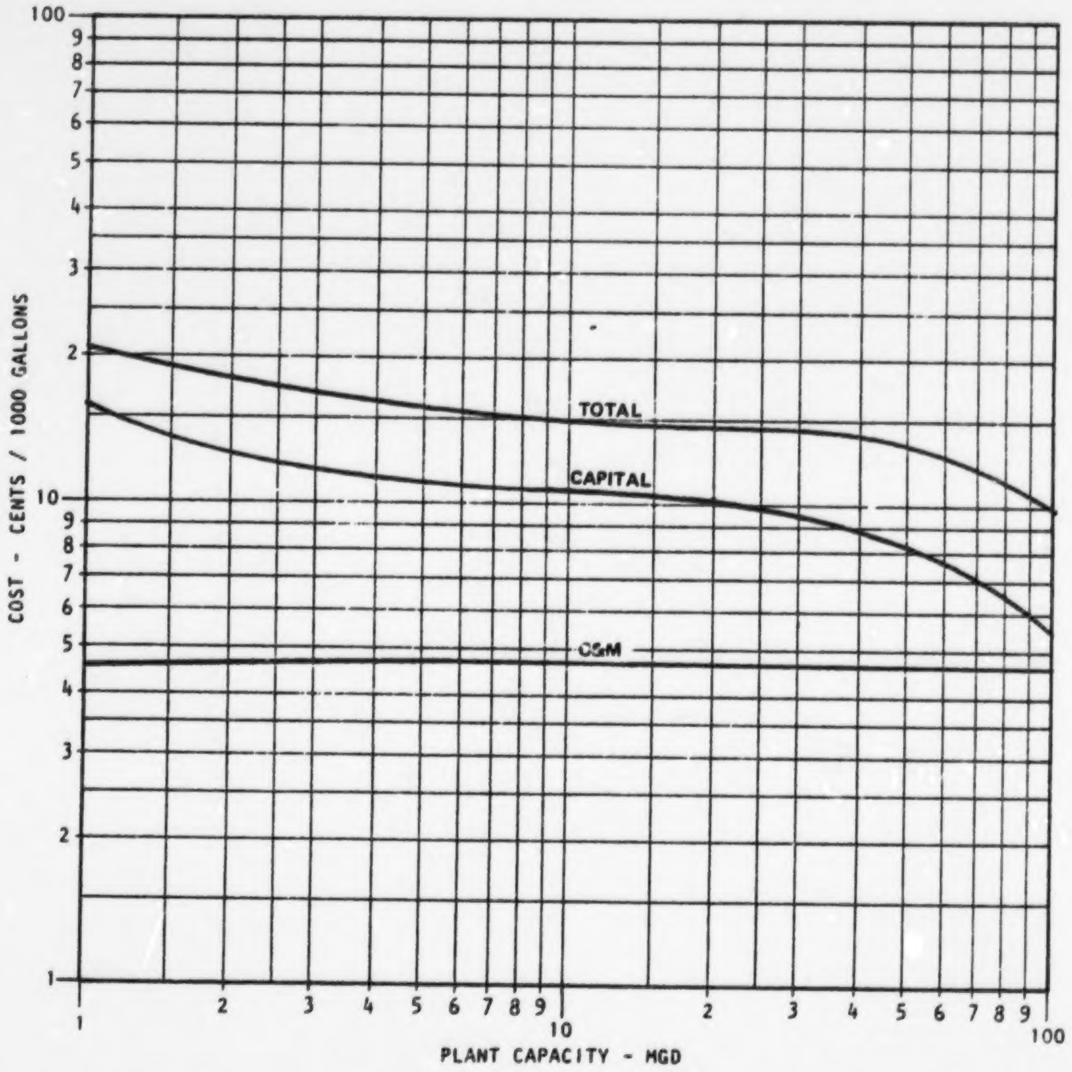

FIGURE 41

E. ACTIVATED CARBON

Influent: Effluent from Filtration D

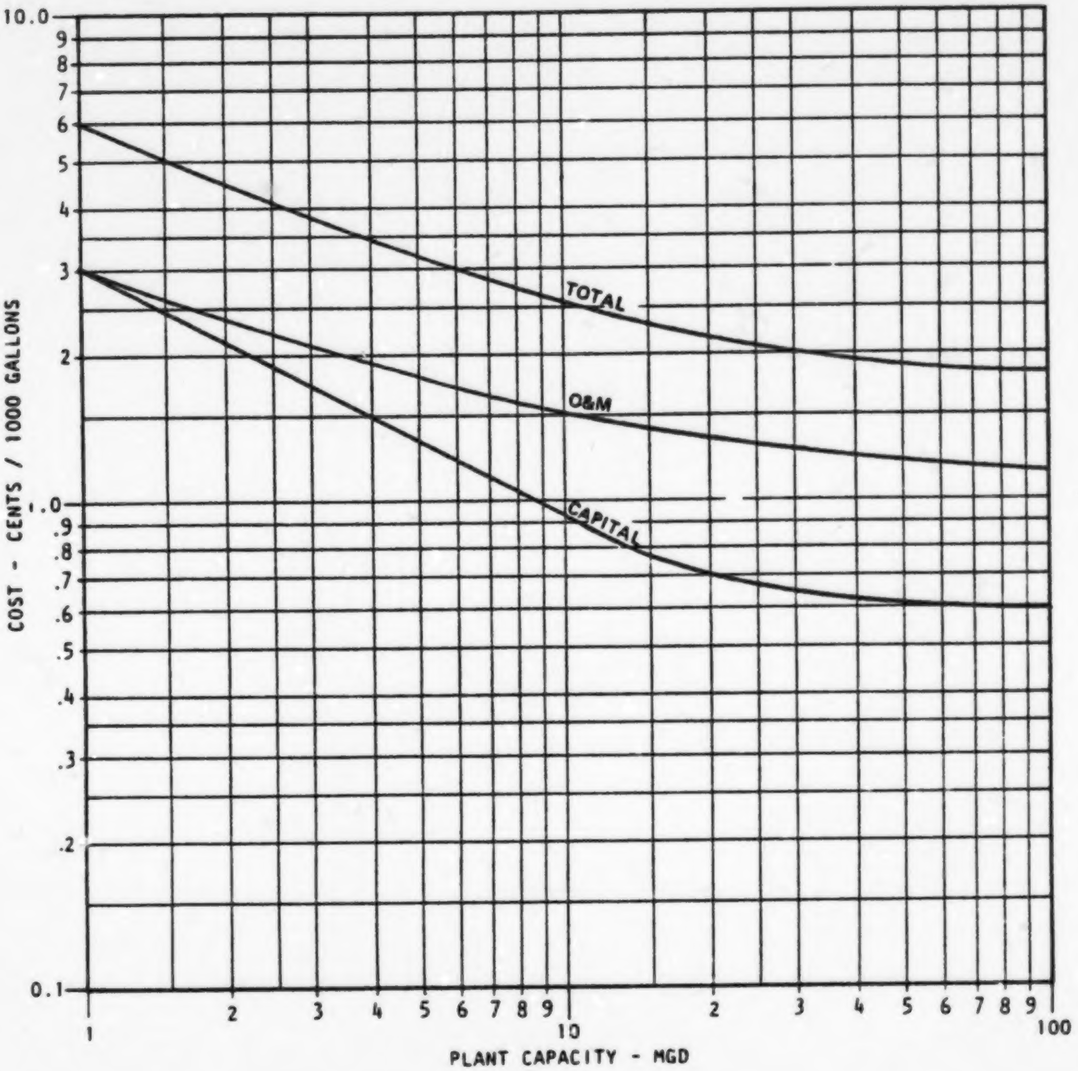

FIGURE 42

O-1. DEWATERING

Sludge Influent: **Primary + Secondary – Conventional or High rate**

A-1 + B-1

A-1 + C-1

A-1 + C-6

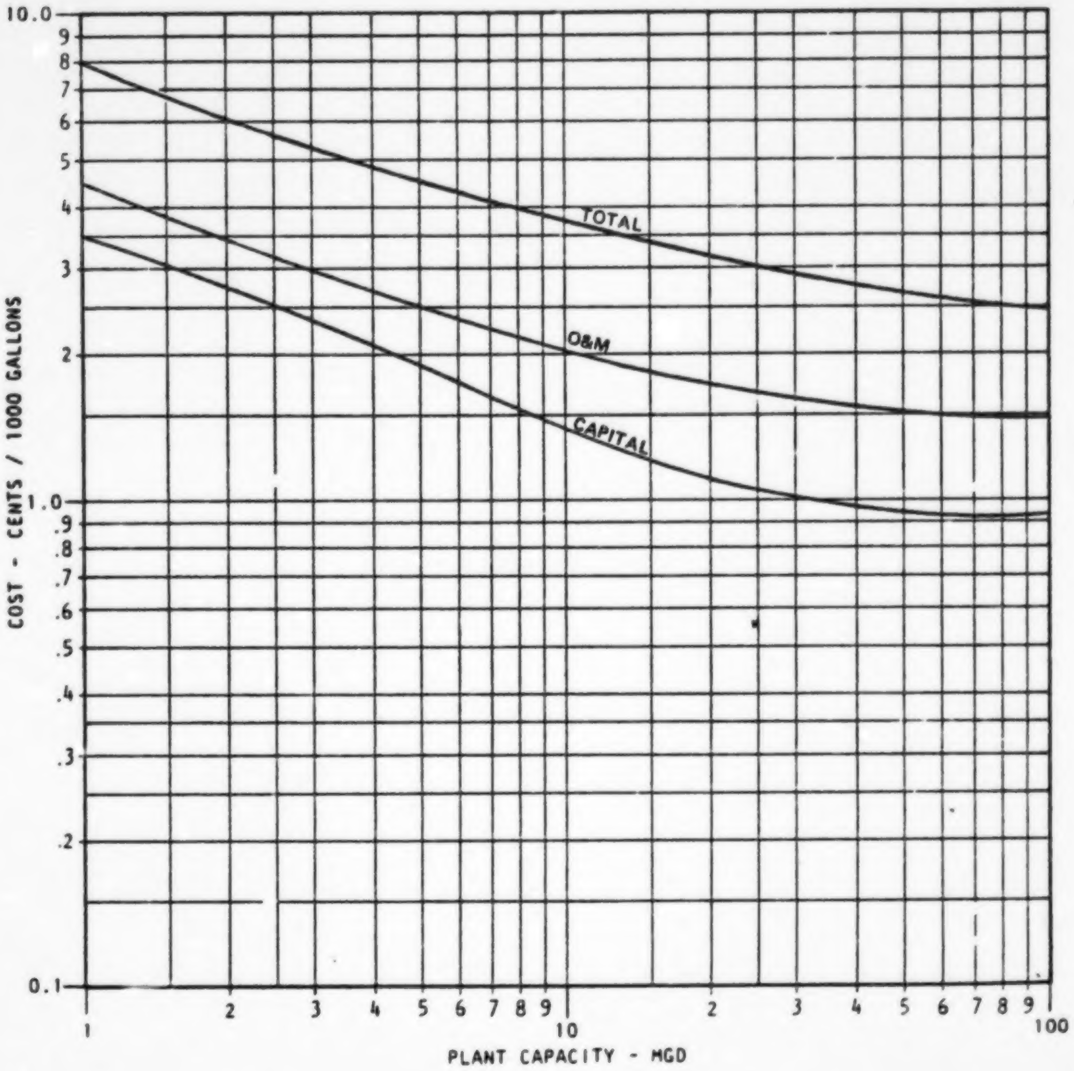

FIGURE 43

O-2. DEWATERING

Sludge Influent: **Primary-Conventional + Secondary-Alum or $FeCl_3$ Addition**
A-1 + C-4 or C-5
A-1 + C-7 or C-8
Primary-Alum or $FeCl_3$ Addition + Secondary
A-4 + B-3
A-4 + C-3
A-5 + B-3
A-5 + C-3

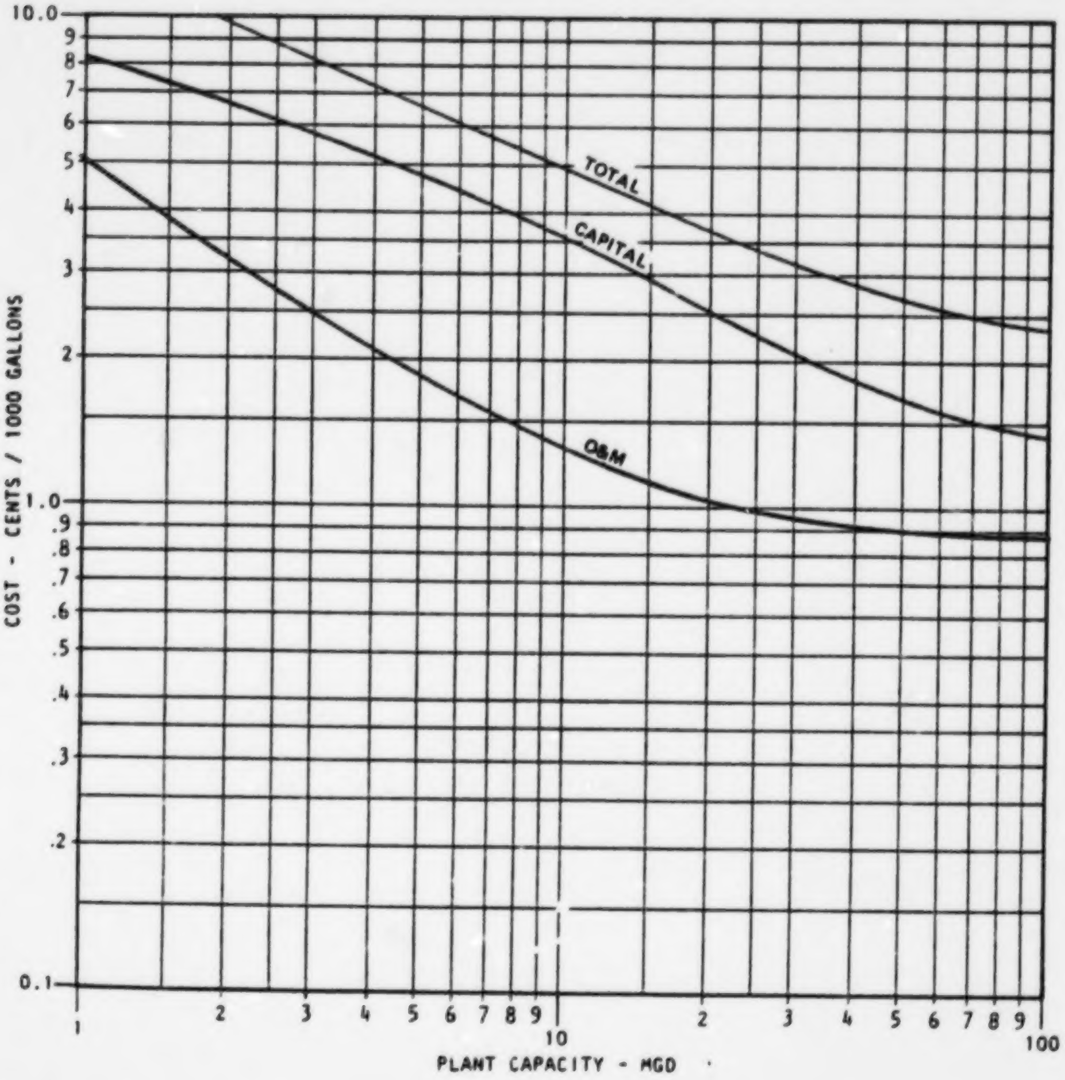

FIGURE 44

P-2. INCINERATION

Sludge Influent: Dewatered Primary + Secondary
(Alum or $FeCl_3$ Addition) 0-2